NASA/TM-2003-212151
AMCOM/AFDD/TR-03-A-001

XV-15 Tiltrotor Aircraft: 1997 Acoustic Testing

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April 2003

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1. INTRODUCTION

This report describes noise testing of the XV-15 tiltrotor aircraft conducted by NASA-Langley Research Center (NASA-LaRC) and Bell Helicopter Textron Incorporated (Bell) during June 1997 at Bell's test site near Waxahachie, Texas. This test represents the second in a series of three such tests directed toward defining low-noise flight procedures for tiltrotors.

Bell supported the tests by providing the aircraft support, test site coordination, and a portion of the acoustic measurements under contract NAS1-20094, Task 10. NASA-LaRC was responsible for overall test direction as well as acoustic and meteorological measurements.

This report describes the test and presents a limited amount of the measured data as analyzed by NASA-LaRC.

1.1 Purpose of Test

Noise impact is considered to be a major obstacle to developing the tiltrotor's full potential within the civil transportation system. If this potential is to be realized, noise reduction must be considered in each new tiltrotor design, and low-noise operating techniques must be defined for all tiltrotors. The purpose of this test was to support the operation of future tiltrotors by developing and demonstrating low-noise flight profiles, while maintaining acceptable handling and ride qualities. Testing was planned around the XV-15 aircraft.

The 1997 XV-15 test is the second in a series of three tests aimed at understanding the noise characteristics of the relatively new tiltrotor aircraft type. The timeline of Figure 1 illustrates the XV-15 acoustic test history. Primary emphasis was given to the approach flight condition where blade-vortex interaction (BVI) dominates. Since this condition influences community noise impact more than any other, an understanding of the noise generating processes could guide the development of low noise flight operations and increase the tiltrotor's acceptance in the community.

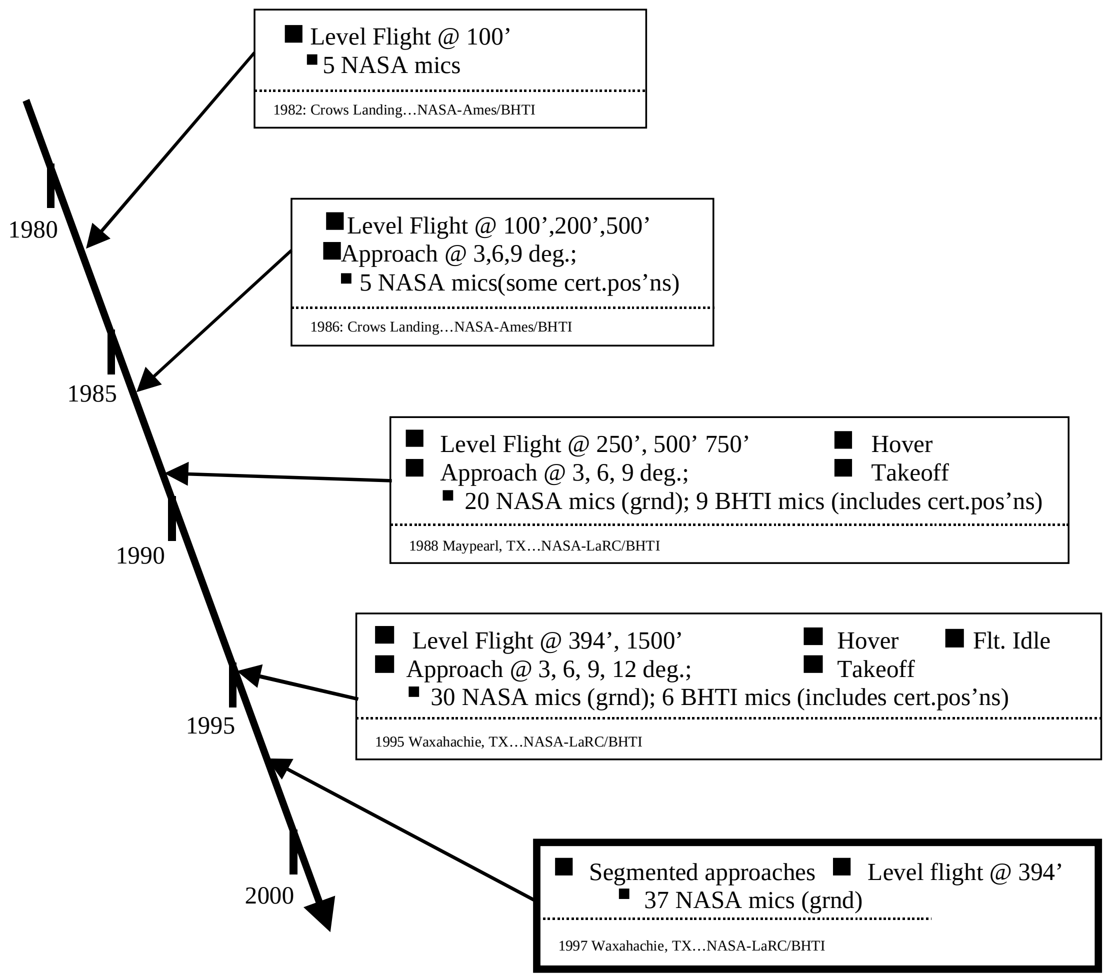


Figure 1. Acoustic testing history of the XV-15 aircraft

In 1995, a test series was initiated to investigate and minimize tiltrotor approach noise. The series was envisioned in these steps:

- Test #1 (completed in 1995): Define broad characteristics of tiltrotor approach noise
- Test #2 (the present test, completed in 1997): Refine approach profiles to incorporate Instrument Flight Rules (IFR) handling qualities constraints, tradeoffs with sound
- Test #3 (scheduled for 1999): Fly optimal approaches to develop and demonstrate most practical, quietest approach profiles

2. TEST DESCRIPTION

Aircraft Description - XV-15

The XV-15 tiltrotor has a design gross weight of 13,200 pounds, and was built by Bell-NASA-Army as a proof-of-concept aircraft and technology demonstrator. Its first flight was in May 1977. It has a fuselage, empennage, and fixed wings similar to those of a conventional airplane, but with an engine/nacelle/rotor assembly that can rotate from the vertical to horizontal, mounted on each wingtip. Each nacelle houses a main transmission and a Lycoming T-53 turboshaft engine capable of generating 1800 shaft horsepower. A cross-shaft connects the two transmissions for transient power transfer and one-engine-inoperative (OEI) operations. Rotor orientation is changed by allowing the nacelles to pivot with respect to the wings. The wing itself is swept forward 6.5 degrees, providing clearance for rotor flapping. The photograph of Figure 2 shows the XV-15 in transitional flight, with nacelles tilted approximately 80 degrees. Only two flight aircraft were built, Serial Numbers 702 and 703. Both have been extensively tested to define the capabilities and limitations of the tiltrotor concept, and have successfully demonstrated the practicality of this new aircraft type. Ship Number 703 was used in the tests described in this report.

The XV-15 has two 25-foot diameter rotors mounted on wingtip nacelles which are capable of tilting from approximately 90 degrees (helicopter mode) to 0 degrees (airplane mode). Each rotor has three highly twisted, square-tip metal blades. These are visible in the photograph of Figure 3. The XV-15 rotors typically operate at 589 RPM during the hover mode and transition, but are reduced to 517 RPM for high-speed forward flight. These RPMs correspond to 98% and 86% of rotor design speed. Major XV-15 aircraft parameters are listed in Table 1. A more detailed description of the XV-15 is available in Reference 1.

Table 1. Test Aircraft Parameters

	XV-15
Test Gross Weight (lb.)	13,200
No. Blades	3
Diameter (ft)	25.0
Rotational Speed (rpm)	
Helicopter Mode	589 (98%)
Airplane Mode	517 (86%)
Rotational Tip Speed (ft/sec)	
Helicopter Mode	771
Airplane Mode	677
Engines	Lycoming T53 (2)

Figure 2. XV-15 in transitional flight

Figure 3. XV-15 on ground

The XV-15 nominal flight envelope for level flight, shown in Figure 4, illustrates the combinations of nacelle angle and airspeed necessary to achieve stabilized level flight. It should be noted that a fairly broad range of nacelle angles and airspeeds is possible within this operating envelope. The acoustic effect of avoiding certain portions of this envelope provides a way to guide flight operations of the XV-15 (and presumably other tiltrotors) in minimizing external noise (see Reference 2). The present test was designed to extend the body of information available to define these effects, incorporating a balance of operationally acceptable handling qualities.

Test Site

The test was performed in a rural area near the town of Waxahachie, Texas, on an available tract of land that had once been the site of the former Superconducting Super Collider (SSC). This site, the same one used in the 1995 XV-15 tests, is sufficiently remote that the ambient noise levels were low, 35-40 dBA, yet allowed flight operation out of Bell's Arlington flight facility. The terrain was flat with few trees, and the ground was covered with short, mowed grass.

The general layout of the test site is sketched in Figure 5, with each microphone location shown. The flight track was selected so the microphones were positioned in the flattest portion of the terrain, away from trees and accessible by vehicle, resulting in an east-to-west 10,000-foot flight track at a heading of 70.3° (True) from North. NASA-LaRC recording equipment was housed in instrumentation vans, each supporting 10 microphone sites. A Bell van supported seven microphone stations at the most up-range portion of the array. A trailer was set up at an elevated site that commanded a view of the flight track to serve as control headquarters for the test.

Since the XV-15 is not equipped with a particle separator, a 75' × 75' concrete helipad was constructed for hovering flight. Figure 6 shows the XV-15 hovering above the pad. The background in the figure shows the typical terrain and topography at this site.

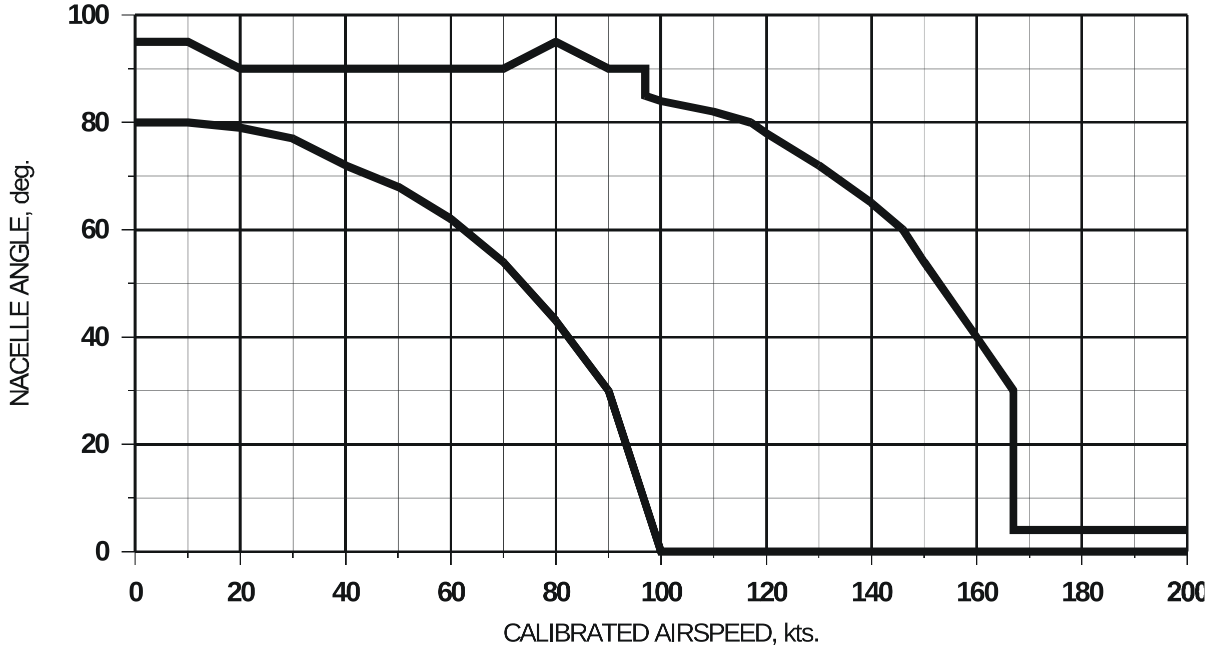


Figure 4. XV-15 Stabilized level flight envelope

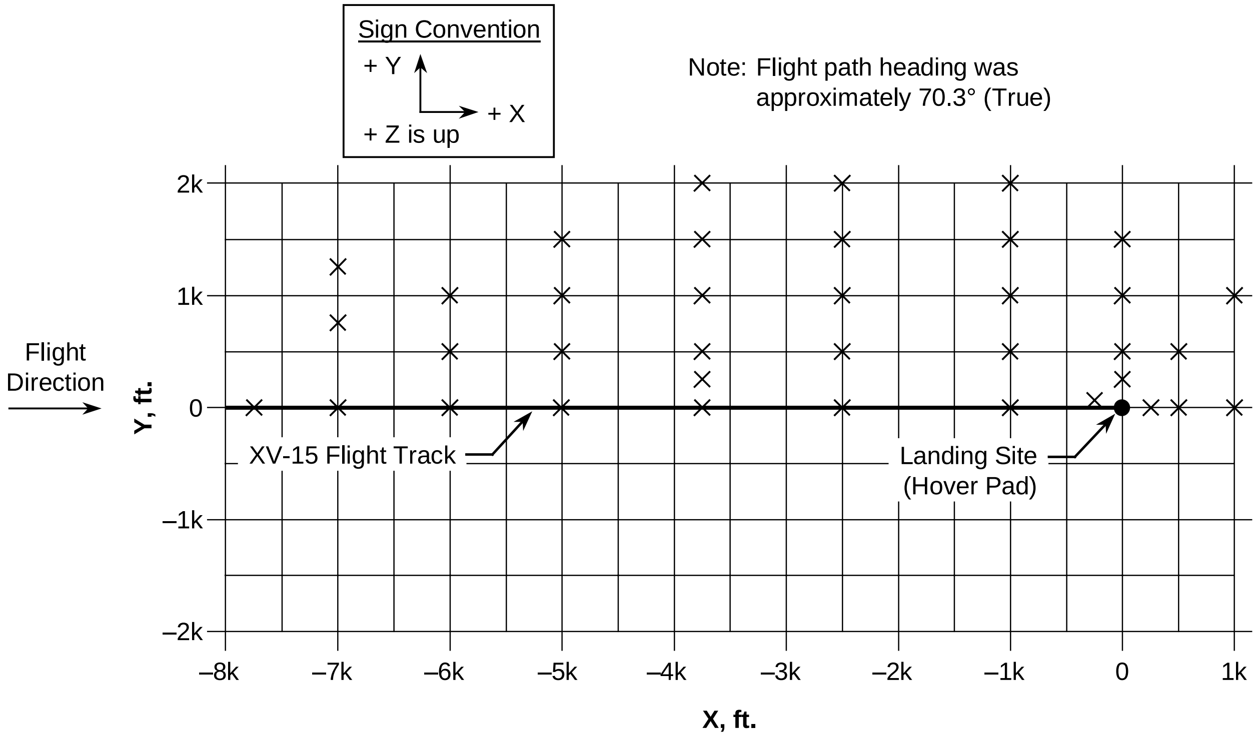


Figure 5. Test site layout showing microphone locations

Figure 6. XV-15 Hovering at test site

Personnel/Crew Assignments

NASA-LaRC was responsible for the overall test direction and for selecting test points and flight procedures. It should be noted that these selections were made with the assistance of handling qualities inputs from Pete Klein of Bell and Bill Decker/Rick Simmons of NASA-Ames/Army. Handling qualities considerations were considered an integral part of the program to ensure that any "low noise" flight operations documented for the XV-15 were practical ones that could realistically be used in a commercial tiltrotor.

NASA-LaRC also provided equipment and personnel for acoustical support at 30 of the 37 microphone locations. They were responsible for meteorological measurements during the test, and for overnight analysis of each dataset. The NASA-LaRC team included personnel on contract from Wyle and Lockheed to provide technical support in data acquisition and analysis.

Bell supported flight operations of the XV-15, providing instrumentation support to monitor and record rotor RPM, nacelle angle, flap angle, airspeed, radar altitude, aircraft position, and time code. Test site coordination and technical support for 7 of the 37 microphone stations was also provided by Bell.

Figure 7 shows some of the test personnel at the mobile office trailers that served as a control headquarters for the test. A list of personnel involved in the test is given in Appendix A. Each individual's responsibilities during the test are given, along with his home organization.

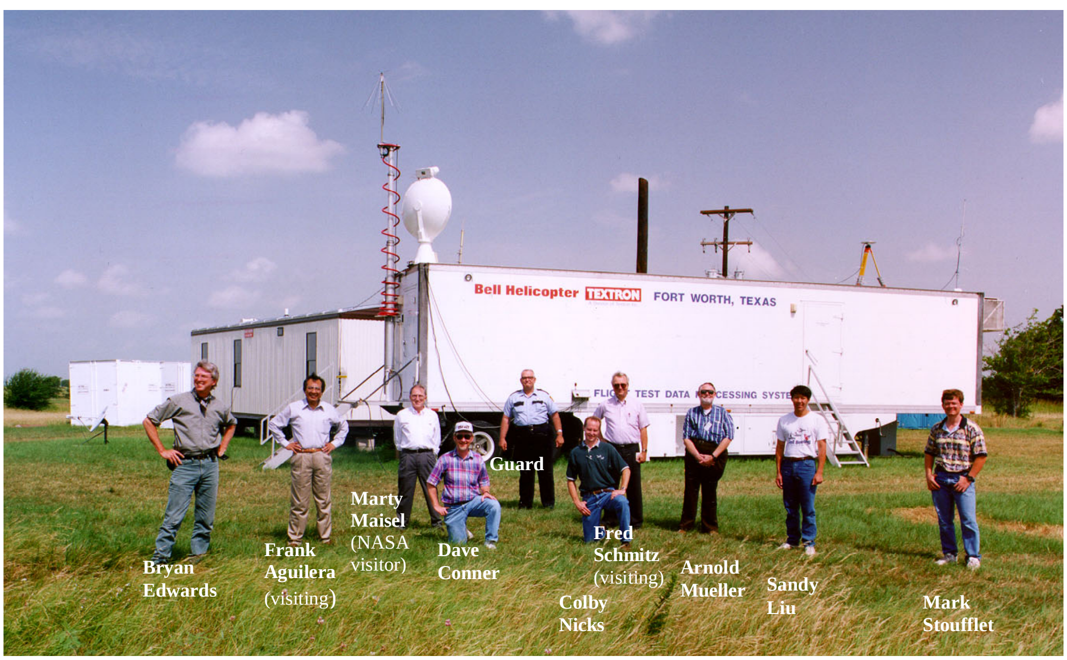


Figure 7. Test personnel at Control Trailer

2.1 Measurement Systems

Instrumentation systems were set up to measure noise, meteorological conditions, aircraft position, and aircraft flight parameters. Personnel operating these systems were in radio contact with the test director, so all were aware when each pass was initiated and concluded. Satellite time code was recorded on each system to provide synchronization of all data for post-test processing.

2.1.1 Acoustic Measurements

For acoustic measurements, instrumentation vans were set up within the array to house recording equipment for the acoustic signals. Three NASA vans supported 10 microphones each, for a total of 30 microphones. A single Bell van supported the other 7 microphones.

The 37 microphones were deployed over a large ground area near the hover pad. All microphones were mounted on ground planes as shown in Figure 8. Symmetry of the sound field about the XV-15's longitudinal axis was assumed, so the microphones were concentrated along only one side of the flight track. The symmetry assumption had been validated in the 1995 XV-15 testing (see Reference 3). The array extended 9000 feet along the approach track (8000' up-range and 1000' downrange), and 2000 feet to the left sideline, as shown earlier in Figure 5. Specific measurement positions are tabulated in Appendix B. This extensive array was designed to measure the acoustic effects of specific approach techniques upon noise near a vertiport terminal.

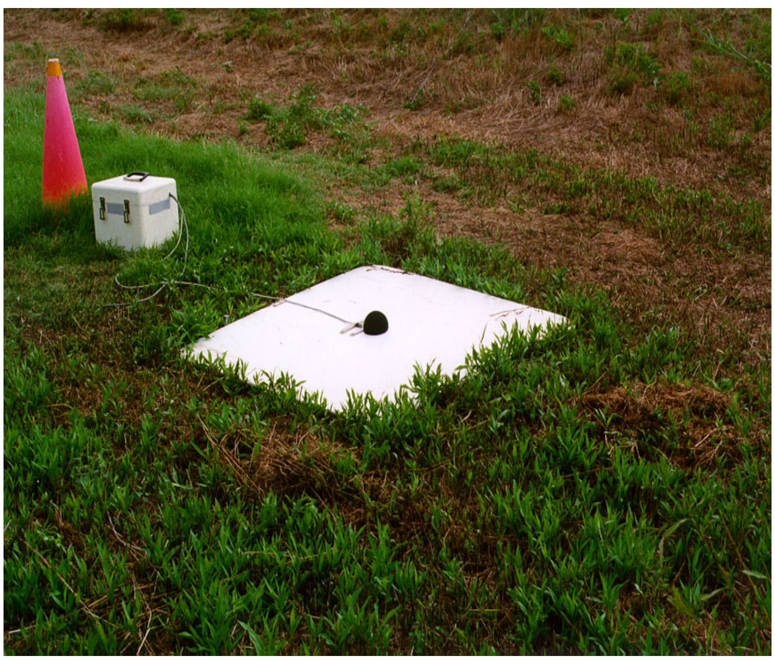


Figure 8. Typical microphone Setup

2.1.2 Meteorological Measurements

Nominal meteorological guidelines for testing were:

- average surface winds less than 10 knots
- relative humidity less than 95%
- no precipitation
- visibility greater than 3 miles (for flight safety), and
- ceiling greater than 1500 feet AGL (for flight safety).

Because of the low wind requirements, early morning flights were scheduled. Based on weather information available at 3:00 PM prior to each potential test day, plans for the next day's testing were confirmed.

During testing, surface meteorological data was recorded at a position near the flight track. In addition, a tethered weather balloon, positioned at the control trailer site, monitored conditions aloft. The balloon was raised and lowered, cycling to altitudes of 1000 feet above ground level. Signals were transmitted to the ground and displayed on a laptop computer.

Meteorological conditions during the test are presented in Appendix C. In general, the winds aloft were higher than desired, and were predominantly out of the West (270 degrees). Since the approaches were made on a heading of 75 degrees, a tailwind component was present for the majority of the flights.

2.1.3 Position Tracking

Position tracking for the XV-15 was accomplished using Global Positioning System (GPS) signals. The XV-15 was fitted with a flight director for providing position and aircraft state guidance to the pilot during approach. This system, while still in development, allowed the desired flight path to be flown very precisely. A parallel system in the control trailer displayed the desired flight path for each approach, with the XV-15's real-time position being overlaid as the approach was flown.

In addition to driving the ground-based and aircraft-based real-time display systems, XV-15 position information was also recorded for use in data analysis. In the recorded data, each position was indicated to an accuracy of ±3 feet, and updated twice each second.

The sign convention for all testing is indicated in Figure 5, shown previously. The center of the helipad served as the origin of the position grid, with X being horizontal distance along the flight track, Y being horizontal distance perpendicular to the flight track, and Z being vertical distance.

2.1.4 Aircraft Parameters

During each flight, aircraft position and a wide variety of aircraft state parameters were recorded on the aircraft. The state parameters recorded include acoustically relevant ones such as rotor speed, nacelle angle, airspeed, and rate of climb/descent. An onboard time code generator was synchronized with a satellite-linked time code unit at the Bell Flight Test Center to provide time correlation between airborne and ground based instrumentation systems. During testing, selected safety of flight data was also transmitted from the aircraft to the command post ground station, where it was monitored continuously.

2.2 XV-15 Testing

Data flights were begun on 7 June 1997, and continued until June 27. A total of 15 flight hours were accumulated during the test. The XV-15 flight operation was based at Bell's Arlington, Texas Flight Test Center, approximately 25 miles distant from the test site. Fuel capacity allowed approximately one hour at the site, during which time 8-9 data passes could normally be completed.

2.2.1 Flight Procedures

Each time the XV-15 arrived at the test site, a level flight pass was made at 60 degrees nacelle and 90 knots airspeed, at a target altitude of 394 feet over the microphones. These "housekeeping" passes were conducted to check the day-to-day consistency of measurements.

A library of some 26-candidate flight procedures was developed prior to the test. These were simply numbered sequentially, with the "housekeeping" procedure being #1, a baseline approach procedure derived from the 1995 test being #2, and potential noise reduction approach procedures being identified as #3 through #26. These candidate procedures are described in Appendix D. Each was programmed into the XV-15 flight director, which provided not only position guidance, but also cues for airspeed, nacelle angle, flaps, power, and other acoustically relevant parameters. The pilot display is shown in the photograph of Figure 9.

Each approach began approximately 5 miles up-range (West) of the microphone array, at an altitude of 1500 to 2000 feet above ground level. At approximately 3 miles up-range, the desired flight procedure was initiated, and the test director radioed “prime data on.” The XV-15 continued along the flight track at an approximate heading of 70 degrees true, passing over the microphone array and flaring to a hover at the center of the hover pad. At this point the test director radioed “prime data off” and data acquisition was discontinued. The XV-15 then climbed out and set up for the next pass. A sequential list of approaches flown during the test is presented in Appendix E.

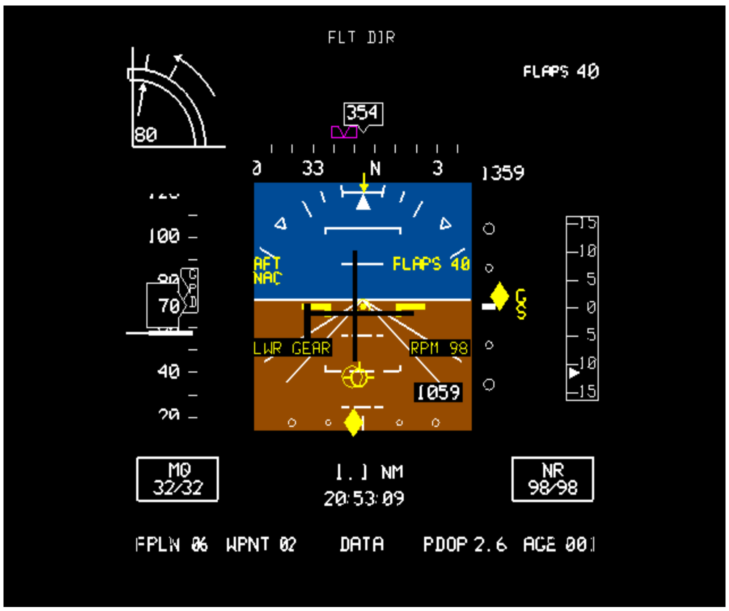


Figure 9. XV-15 flight director display

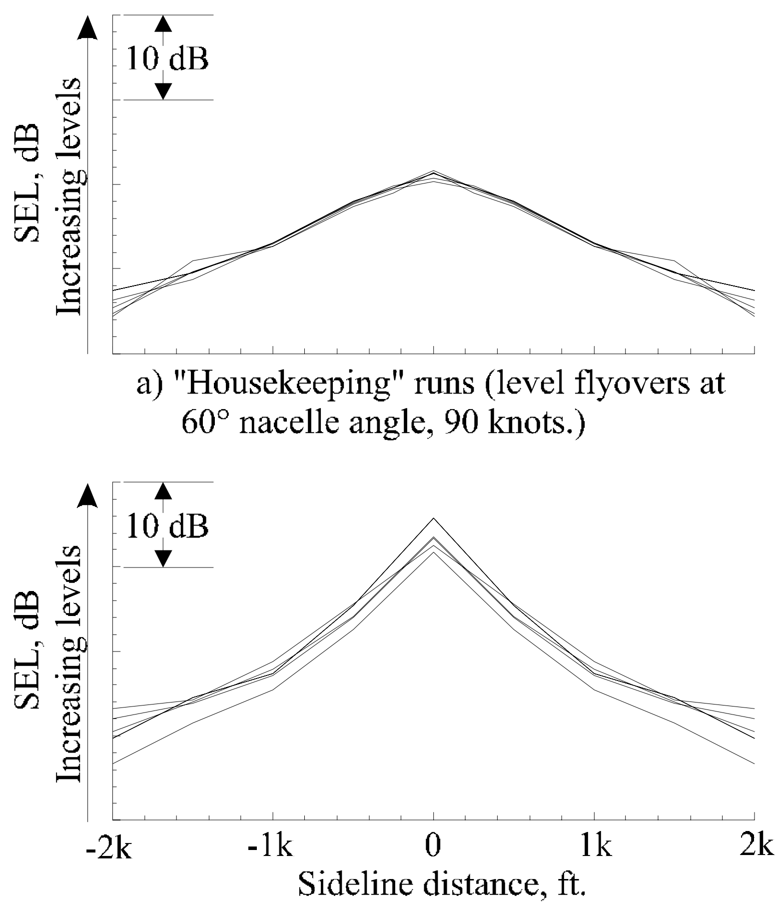
Since information on handling qualities for each of the approach procedures was desired, the pilot was requested to comment on each pass. An on-board video recorder had been installed to record the flight director screen during the entire test. Pilot comments were recorded on the audio track of this recorder. These were transcribed, and are presented in Appendix F.

2.2.2 Results and Discussion

The primary test results of this test have been presented in public forums (Ref. 8), and are summarized below. These results include a discussion of data repeatability, approach procedures, noise data in the form of Sound Exposure Levels deltas, noise “footprints,” and relative benefits of using noise abatement flight procedures.

2.2.2.1 *Data Repeatability*

To examine the repeatability of the data, Figures 10a and 10b illustrate the comparison of the sound exposure levels for all the housekeeping runs and 6° approaches, respectively. The data shown are from the most densely populated line of microphones located 3750 feet up-range. The figures show that, as one would expect, the maximum sound exposure levels were measured on the flight path centerline and the levels decrease rapidly with increasing sideline distance. For the housekeeping runs of Figure 10a, the SEL variation for the centerline microphone and all microphones up to 1000 feet to the sideline are ±0.6 dB or less. The largest SEL variations are approximately ±1.6 dB for the microphones located 1500 and 2000 feet to the sideline. Figure 10b shows that the SEL variation for the 6° approaches was ±2.3 dB or less for all microphones except the farthest out microphone located 2000 feet to the sideline, which had a slightly greater variation of ± 2.8 dB. These variations are consistent with what has been measured in previous XV-15 acoustic flight tests.



a) "Housekeeping" runs (level flyovers at 60° nacelle angle, 90 knots.)

b) 6° approaches to IGE hover.

Figure 10. Sound exposure levels for multiple runs at same flight conditions as measured at line of microphones 3750 feet up-range of landing point

2.2.2.2 Approaches

Of the sixty runs flown during this test, five runs, each a different approach profile type, were selected for presentation in this report, as follows:

1) A standard 6° approach - baseline
   This approach, derived from the 1995 XV-15 flight test program was determined to be a very comfortable (from the standpoint of pilot workload) approach by the pilots, with excellent handling qualities, and is also close to a typical FAA noise certification approach for conventional helicopters. For these reasons, the 6° approach was selected to be the "baseline" against which all other approach procedures would be compared.
2) 3° approach
3) 9° approach
4) 3° to 9° approach, Profile "A", and
5) 3° to 9° approach, Profile "B"

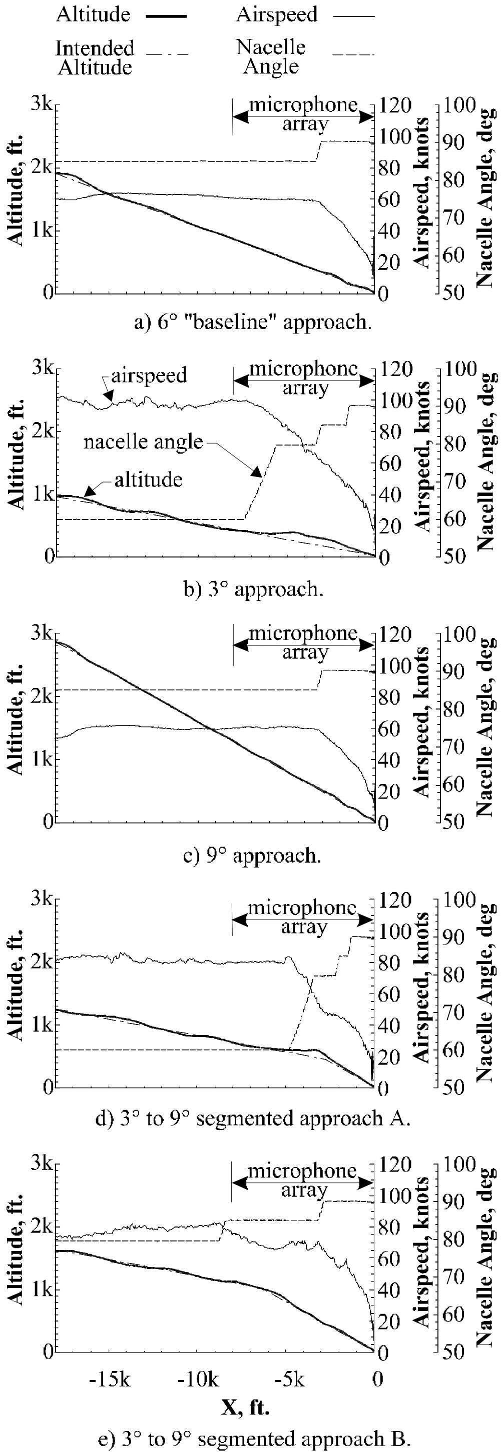
In each approach, the XV-15's nacelle angle, glideslope schedule was tailored to provide the best tradeoff between acceptable handling qualities and minimum noise.

In the text below, each approach procedure will first be described in detail, followed by a discussion of the noise footprint characteristics and a comparison with the 6° approach profile.

2.2.2.3 Approach Profiles

The primary approach profile parameters for the five selected approaches are shown in Figures 11a through 11e. Each part of the figure presents the altitude, airspeed, and nacelle angle as a function of the up-range distance for a single approach type. The initial glideslope was intercepted at a distance of 18,000 feet up-range of the landing point for all approaches. A dash-dot line indicates the intended or desired flight path. It should be noted that while the approach profiles were designed using airspeed, they were flown using ground speed. Prevailing tailwinds of approximately 10 to 15 knots persisted during most of this test, resulting in lower airspeeds than anticipated. All the profiles presented in this report were flown in tailwinds of about 10 knots.

For the 6° approach profile (Figure 11a), the aircraft intercepted the 6° glideslope at an altitude of about 1900 feet with approximately 60 knots airspeed and a nacelle angle of 85°. This approach was designed for a 70-knot airspeed; however, 10-knot tailwinds resulted in an airspeed of about 60 knots. The 85° nacelle angle, 60 knots condition was maintained until the aircraft was approximately 3300 feet up-range, where the nacelles were rotated to 90° and a deceleration to 40 knots was begun. At about 1800 feet up-range the aircraft began decelerating to achieve an IGE hover at the landing point. As mentioned earlier, the pilot considered this to be a very comfortable approach.



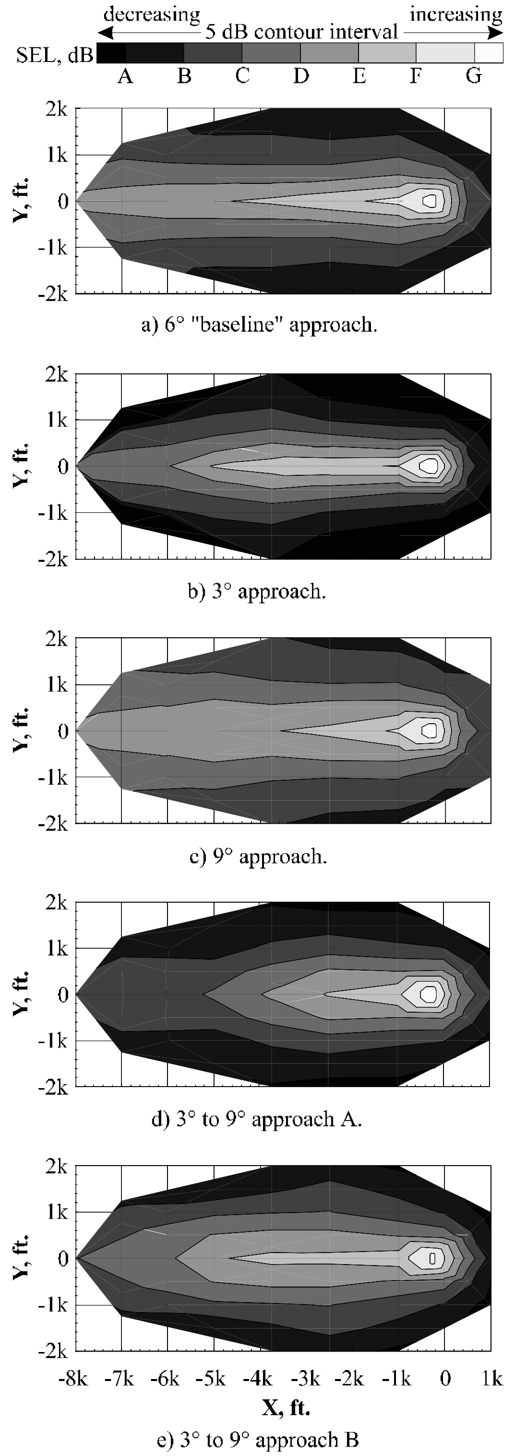


Figure 11. Approach profile characteristics

Figure 12. Sound exposure level ground contour

For the 3° approach profile (Figure 11b), the aircraft intercepted the 3° glideslope at an altitude of about 950 feet and followed a nacelle angle/airspeed schedule very different from that of the 6° approach. This approach began with a nacelle angle of 60° and airspeed of about 100 knots. This nacelle angle and airspeed was maintained until the aircraft was 7500 feet up-range, where the nacelles were rotated to 80° and a deceleration to 60 knots was initiated. At a distance of about 3300 feet up-range, the nacelles were rotated to 85° and a deceleration to 40 knots was initiated. Finally, the nacelles were rotated to 90° at the point about 1800 feet up-range and the final deceleration to an IGE hover at the landing point was initiated. The pilot described this approach as “controllable, adequate performance and tolerable workload.” However, he also commented he would have preferred to convert to a 90° nacelle angle sooner and to be allowed to convert to 95° towards the end to decrease the nose up attitude to provide a better visual view of the landing point. Conversions to 95° were not allowed due to the IFR approach constraints and for safety considerations in the case of an engine out.

For the 9° approach profile (Figure 11c), the aircraft intercepted the 9° glideslope at an altitude of about 2900 feet and followed the same nacelle angle/airspeed schedule as that of the 6° approach. The approach began with approximately 60 knots airspeed and a nacelle angle of 85°. At an up-range distance of about 3300 feet the nacelles were rotated to 90° and a deceleration to 40 knots was initiated. Deceleration to an IGE hover at the landing point was initiated about 1800 feet up-range. The pilot considered this to be a comfortable approach all the way in and commented “very controllable, achieved adequate performance, tolerable workload.”

The 3° to 9° segmented approach profile A, shown in Figure 6d, followed a nacelle angle/airspeed schedule similar to that of the 3° approach. It had a glideslope intercept of the initial 3° glideslope at an altitude of about 1250 feet with approximately 80 knots airspeed and a nacelle angle of 60°. At a distance of about 4800 feet up-range the nacelles were rotated to 80° and a deceleration to about 60 knots was initiated. The guidance provided by the flight director system during this test did not include compensation for the aerodynamic coupling between nacelle rotation and rate of climb due to the rotation of the thrust vector. Just prior to intercepting the 9° glideslope at about 2700 feet up-range and an intended altitude of about 450 feet, the aircraft deviated above the intended glideslope path by more than 100 feet due to nacelle rotation. Compensation for nacelle rotation was integrated into the flight director system during a subsequent flight director development program that is documented in Reference 4. At about 2100 feet up-range, the nacelles were rotated to 85° and a deceleration to 40 knots was initiated. At about 1500 feet up-range the nacelles were rotated to 90° and the final deceleration to an IGE hover was initiated. The pilot found this approach unacceptable because “the profile keeps too high a nacelle angle for the airspeed….don’t like the (tail) buffeting vibrations on the descent.”

The 3° to 9° approach profile B was designed to maintain the airspeed schedule of profile A but alter the nacelle schedule. It intercepted the initial 3° glideslope at an altitude of about 1650 feet, a nacelle angle of 80° and airspeed of 80 knots. At approximately 8700 feet up-range the nacelles were rotated to 85° and a deceleration to 70 knots was initiated. The 9° glideslope was intercepted at an up-range distance of about 6200 feet and an altitude of about 1000 feet. At about 3100 feet up-range the nacelles were rotated to 90° and a deceleration to 50 knots was initiated. Finally, at about 1800 feet up-range the deceleration to an IGE hover was initiated. The increased nacelle angle schedule in this approach was an attempt to take into account the pilot's concerns from the 3° to 9° approach profile A. The pilot indicated that this approach was much more acceptable, though there was still significant tail buffeting occurring.

2.2.2.4 Ground Contours

Figure 12 shows the characteristics of the resulting noise footprints for the same five approaches presented in Figure 11. The separation in the contour levels is 5 dBSEL and the contour levels are labeled from A to G with A representing the lowest SEL, shown as black in the figure, and G representing the highest SEL, shown as white in the figure. The contour scales for all parts of Figure 12 represent identical values to allow for direct comparisons. Each footprint extends from 1000 feet down-range to 8000 feet up-range of the landing point and spans up to 2000 feet to either side of the landing point, covering an area of more than 650 acres. The XV-15 approached from the left in the figure, along a line at Y = 0, coming to an IGE hover at about 20 feet AGL over the hover pad located at X = Y = 0. The noise footprints are most useful to provide a qualitative assessment of the noise abatement potential of the different approach profiles. The contour data will be presented in other formats later in the report that will provide for an easier quantitative assessment.

The noise footprint for the 6° "baseline" approach is presented in Figure 12a. The highest SEL contour is located along the flight path between approximately 200 and 500 feet up-range of the hover pad ($-500 \leq \times \leq -200$) and extends about 150 feet to the sidelines. The maximum SEL is not located about the hover pad due to a combination of the microphone distribution around the hover pad and the linear interpolation technique between the measurement locations used by the graphics software. Safety concerns, as well as rotor-downwash-generated wind noise, precluded locating a microphone on the hover pad. In general, the maximum levels are located about the hover point and decrease rapidly with increasing sideline distance and with increasing down-range distance. The contours decrease least rapidly along the flight path up-range of the hover point, i.e. the area the aircraft actually flies over. More specifically, the F contour level extends from about X = 0 to X = -1000 and about 250 feet to both sidelines with a narrow "tail" that extends to about 1700 feet up-range. Each successively lower SEL contour is a little larger, extending a little further in front of and to the sides of the hover pad. Up-range along the flight path the contour "tails" increase in both length and width with decreasing contour level. For the contour levels of D and below, the contours "tails" extend up-range beyond the area of the measured noise footprint.

Figure 12b shows the noise footprint for the 3° approach. Compared to the 6° approach, the contour levels generally fall off more rapidly with increasing distance from the landing point. While the E contour level extends about 500 feet further up-range, the D contour level has been shortened significantly and is contained within the boundaries of the measurement area. For the SEL contour levels below E, the decreased sideline width far up-range indicates that the up-range lengths of these contours have also been significantly decreased. This 3° approach appears to be somewhat less noisy compared to the 6° approach and in fact the average SEL for all microphones has been reduced by 3.3 dB.

The noise footprint for the 9° approach is presented in Figure 12c. Compared to the 6° approach, the contour levels generally fall off less rapidly with increasing distance from the landing point. For this approach, the E and F contour levels are a little smaller while all the contour levels below E are somewhat larger. This 9° approach appears somewhat louder than the 6° approach even though the aircraft was at a higher altitude and thus a greater distance from the microphones. The average SEL for all microphones has been increased by 1.5 dB compared to the 6° approach.

The approach footprint for the 3° to 9° approach profile A is presented in Figure 12d. All SEL contour levels for this approach are smaller when compared to those for the 6° approach. In fact, the contour levels of E and below are significantly smaller and contour levels C through G are all completely contained within the measurement area. This approach appears to be the quietest approach presented with a reduction in the average SEL of 3.6 dB.

The approach footprint for the 3° to 9° approach profile B is presented in Figure 12e. While all the SEL contour levels appear to be smaller than those for the 6° approach, they are somewhat larger than those for the 3° to 9° approach profile A. This increase is most likely due to the 80° nacelle angle during the early part of the approach compared to a 60° nacelle angle for the 3° to 9° approach A. The most significant noise reductions are at the most up-range areas for the C and D contour levels, which are both contained within the measurement area. This approach appears to be less noisy than the 6° approach but the average SEL for all microphones has been reduced by only 0.6 dB.

2.2.2.5 Sideline Sound Exposure Levels

To provide a more quantitative assessment of the SEL differences for the different approach profiles, Figure 13 presents the SELs as a function of the sideline distance for a number of up-range slices across the noise footprint. More specifically, Figures 13a through 13f present the SELs for the five approaches as a function of sideline distance for slices across the noise footprint located 1000, 2500, 3750, 5000, 6000, and 7000 feet up-range of the landing point, respectively.

For the slice 1000 feet up-range, Figure 13a shows that the maximum levels were measured on the centerline and the levels fall off quickly with increasing sideline distance. On the centerline, the 6° approach has the highest SEL while the 3° to 9° approach B has the lowest SEL and the difference is about 4 dB. However, for the sideline measurement locations the 9° approach generally has the highest SEL while the 3° to 9° approach A has by far the lowest SEL. At the 1500-foot sideline distance the 3° to 9° approach A is almost 10 dBSEL lower than the 9° approach and more than 7 dB lower than the 6° approach.

Moving further up-range to the 2500 foot slice shown in Figure 8b, the 3° and 6° approaches have the highest levels on the centerline while all the other approaches are about 3 dB lower. For all sideline measurement locations the 3° approach has the lowest level. At 2000 feet to the sideline the 3° approach is almost 6 dB lower than the 6° approach.

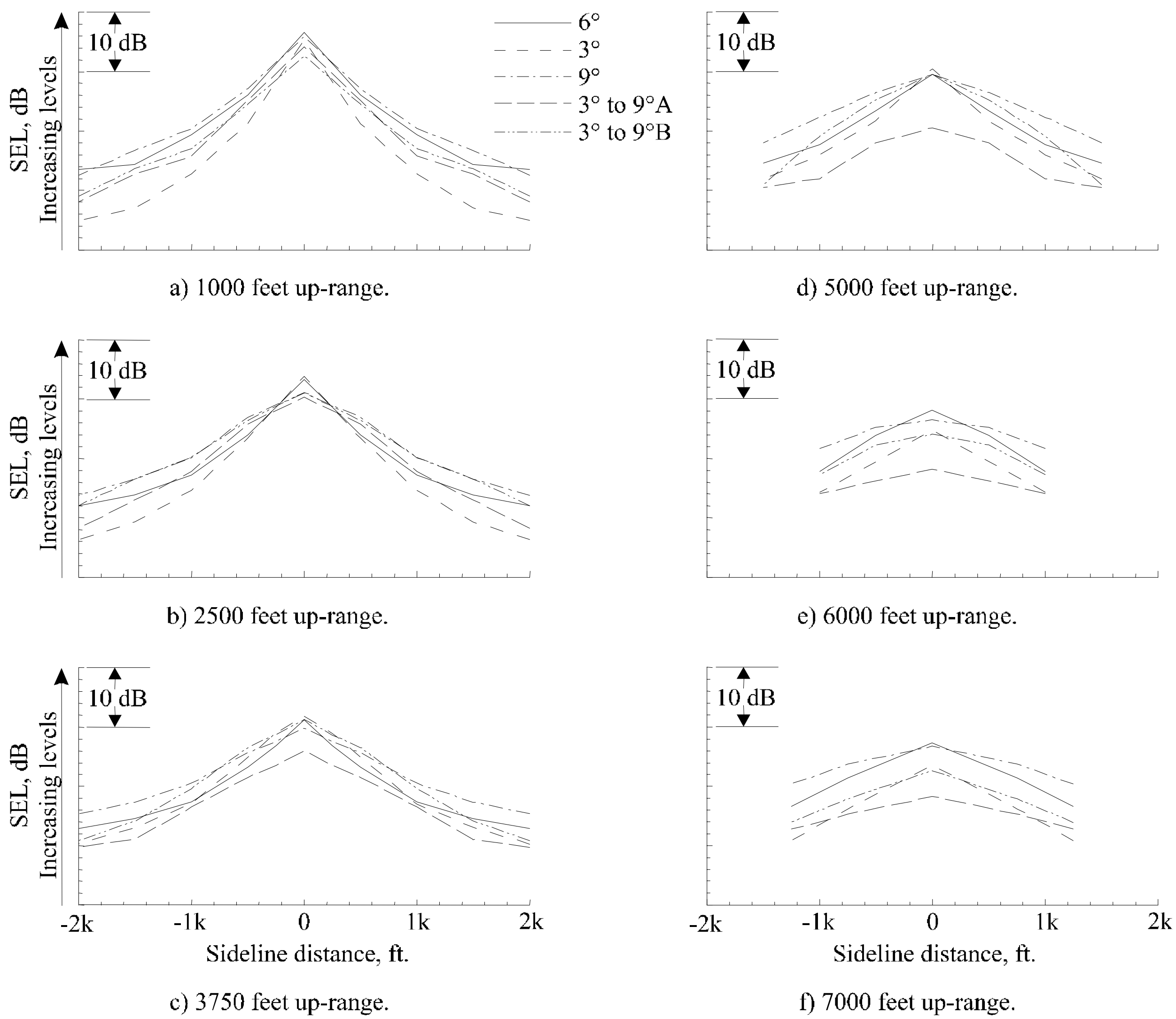


Figure 13. Sound exposure levels as a function of sideline distance

At 3750 feet up-range the 3° and 6° approaches again have the highest levels on centerline, along with the 3° to 9° approach B. The 3° to 9° approach A had the lowest levels on centerline and at all the sideline measurement locations. Compared to the 6° approach, this approach is about 6 dB down on centerline and about 3 dB down at 2000 feet to the sideline. The 9° three outermost sideline locations are about 2 to 3 dB higher than the 6° approach.

At 5000 feet up-range (Figure 13d) all approaches have about the same centerline SEL with the exception of the 3° to 9° approach A, which is almost 10 dB down. Again, the 3° to 9° approach A has the lowest levels for all measurement locations and is about 4 to 6 dB down from the 6° approach at all sideline locations. At between 3 and 5 dB higher than the 6° approach, the 9° approach has the highest levels on the sidelines.

At 6000 feet up-range, the 6° approach has the highest level on centerline while the 9° approach has the highest levels at all sideline locations. Once again, the 3° to 9° approach A has the lowest levels at all measurement locations. Compared to the 6° approach, this approach is 10 dB down on centerline and between 4 and 6 dB down on the sidelines.

The 6° approach is again the highest on centerline at 7000 feet up-range (Figure 13f) and the 9° approach is highest on the sidelines. The 3° to 9° approach A is lowest on centerline and at 750 feet to the sideline; however, the 3° approach is lowest 1250 feet to the sideline. Compared to the 6° approach, the 3° to 9° approach A is about 9 dB down on centerline and about 6 dB down at the sideline locations.

As a function of up-range distance, Figure 13 shows that the SEL variation on centerline for the five approaches increased from a minimum of about 4 dB 1000 feet up-range to a maximum of nearly 10 dB at 5000 feet and further up-range. The 6° approach had the highest levels, or very nearly the highest levels, on centerline at all up-range distances. The 9° approach tended to have the highest levels for all the sideline measurement locations at all the up-range distances. The 3° approach had some of the highest levels on centerline for up-range distances up to 5000 feet while simultaneously having some of the lowest levels at the sideline measurement locations. At up-range distances of 6000 and 7000 feet, the 3° approach had some of the lowest sideline levels and moderate centerline levels. While being pretty much middle of the pack at 1000 and 2500 feet up-range, the 3° to 9° approach A had the lowest levels for nearly all measurement locations from 3750 feet to 7000 feet up-range, in many cases by a large margin. This approach has lower noise levels earlier in the approach during the quieter 3° approach segment and higher levels near the end of the approach during the louder 9° approach segment. The 3° to 9° approach B did not seem to benefit from the 3° approach segment, probably because of the higher nacelle angle compared the 3° approach, and during the 3° portion of the 3° to 9° approach A.

2.2.2.6 Average Sound Exposure Levels

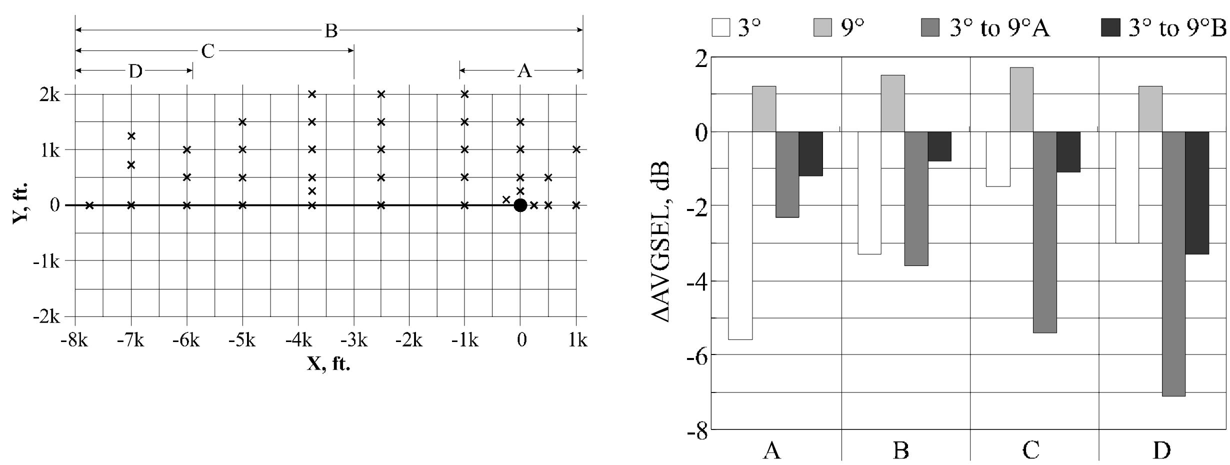
Another type of assessment of the SEL differences for the different approach profiles that is more quantitative is to compare the average SEL (AVGSEL) for all microphones, or for a given subset of the microphones. Figure 14a and Table 2 identify the different microphone sets that were averaged and presented here. Figure 14b presents the difference in the average SEL between the 6° approach and each of the other approaches as a function of the microphone set.

A negative AVGSEL means that the average SEL has been reduced compared to the 6° baseline approach. This figure shows that the 9° approach had the highest levels for all microphone sets presented with an ΔAVGSEL of between 1 and 2 dB. The 3° to 9° approach profile B was about 1 dBSEL quieter than the baseline for all microphone sets except Set D, which was a little more than 3 dBSEL quieter. The 3° approach is the quietest approach around the landing point (Set A) with an ΔAVGSEL of about –5.5 dB. This may be because the lower rate of descent requires less of a flare at the end of the approach to achieve a hover condition. For the average SEL using all the microphones (Set B), the 3° approach is a little more than 3 dBSEL quieter than the baseline approach while Sets C and D show less noise reduction with ΔAVGSELs of about –1.5 and –3 dBSEL, respectively. The 3° to 9° approach profile A shows the greatest noise reduction for all microphone sets except around the hover pad. The noise benefits for this approach increase as you move to the progressively up-range microphone sets. For Set D, the average SEL has been reduced by more than 7 dBSEL compared to the 6° baseline approach.

Table 2. Microphone set identification

Microphone set ID	Microphones used in average
A	All microphones between 1000 feet down-range and 1000 feet up-range of the landing point
B	All microphones
C	All microphones between 3000 and 8000 feet up-range of the landing point
D	All microphones between 6000 and 8000 feet up-range of the landing point

This figure indicates that the 3° to 9° approach profile A provides the greatest noise abatement for all areas of the measured footprint except near the landing point.



a) Microphone set ID

b) SEL difference from 6° baseline approach.

Figure 14. Average SEL difference for different microphone sets

2.2.2.7 Contour Areas

One final way to assess the noise abatement potential of the different approach profiles is to compare the ground contour areas exposed to a given noise level. Figure 15 presents the contour area in percentage of the total measurement area as a function of the relative SEL for the five different approaches. At the lowest levels, all the approaches converge to 100% of the measurement area. At the highest levels, all approaches eventually converge to 0% of the measurement area. For a given contour area, the largest differences in areas between the different approaches are found at the lowest noise levels while the smallest differences are found at the highest noise levels. This figure clearly shows that the 9° approach had the largest contour areas for all but the highest levels. The curves for the 6° approach and the 3° to 9° approach B are very similar except at the lower levels, where the contour area for the 6° approach is larger. The 3° approach and the 3° to 9° approach A have the smallest contour areas for all levels except the very highest, where the areas are quite small anyway. The 3° approach has smaller areas at the lower levels while the 3° to 9° approach A has smaller areas at the moderate levels. This figure also clearly demonstrates that the 3° approach and the 3° to 9° approach A are the quietest runs considered in this report.

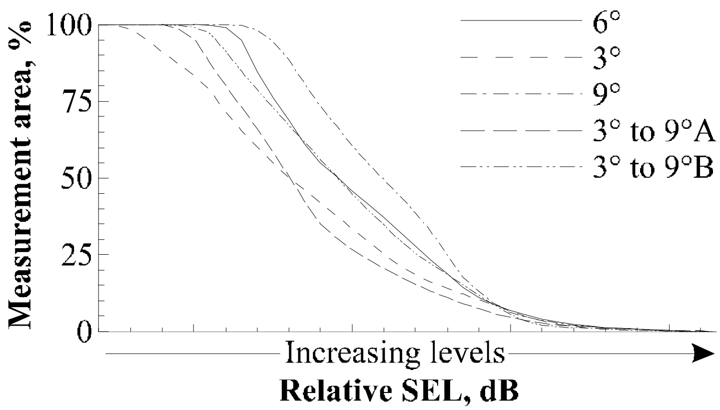


Figure 15. Sound exposure level ground contour areas as a percentage of total measurement area.

2.2.2.8 Impact of the Flight Director and Handling Qualities on Noise Abatement Procedures

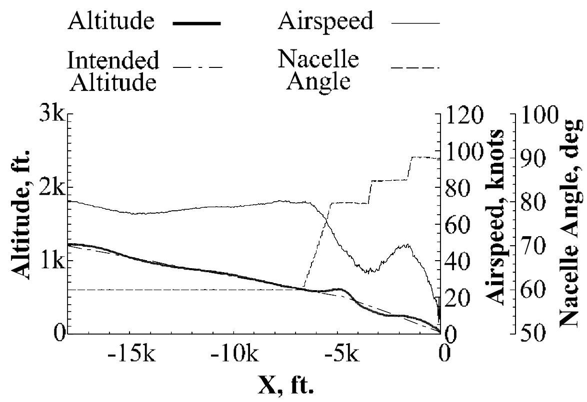
In previous testing (Ref. 3), no formal flight director was available, and the target profiles were flown as "Visual Flight Rules" (VFR) approaches. Although a localizer-type needle was available to give lateral position indications, the pilot used predominantly "heads-up" visual cues for each approach. This allowed the transition from airplane mode to begin relatively near the touchdown point. In these earlier tests, the noise reduction flexibility of the tiltrotor was clearly apparent, since the aircraft remained in the relatively quiet low-nacelle flight regime until very near the landing point. In some cases, the full transition from airplane mode to helicopter mode was performed over the microphone array.

In the present test, the profiles were flown as “Instrument Flight Rules” (IFR) approaches using the newly developed flight director. This allowed much more repeatable, precise profiles, but ones that were necessarily limited by the pilot’s IFR workload. To allow enough time for the pilot to assimilate the flight director’s visual cues and translate them into control inputs, an approximately 5 second time delay, or buffer, had to be allowed for after each pilot instruction. This buffer produced an elongated approach.

The attempt to concentrate active approach maneuvering over the microphone array resulted in approach profile planning segments more aggressive than suggested for routine instrument operations, as derived from simulator experience (Ref. 5). Experience with simulated tiltrotor instrument approaches suggests keeping the aircraft pitch attitude modest and making gentle flight condition changes. Evidence of pilot workload increase came from both handling qualities commentary and task performance and also was indicated by tracking performance. Figure 16 exemplifies the results of high pilot workload. This profile featured a two-segment 3° to 6° approach. Profile airspeed commands attempted to continuously decelerate on the two-segment approach path, with no "settling time" breaks. As shown in Figure 16a the aircraft decelerated too rapidly prior to the glide slope break between the 3° and 6° flight path angles at X = -4500 feet. The rapid deceleration combined with the nacelle change from 60° to 80° resulted in the aircraft initially rising over and then rapidly dropping under the intended flight path. Pilot commentary pointed to the difficulty faced by the pilot with so many rapid changes in flight condition. The resulting noise footprint, seen in Figure 16b shows a noise “hot spot” as a result of poor altitude and airspeed tracking. Subsequent flight profiles provided the five-second buffer between major flight condition changes. Modest flight condition changes, such as 5° nacelle movements, gentle commanded decelerations and appropriate buffer times resulted in much tighter tracking of the intended flight profile.

The data from this test indicate the XV-15 was at much higher nacelle angles (60° to 85°) while over the microphone array than was the case in previous (1995) testing. This was a natural result of the progression to the new flight director due to the time required for the pilot to assimilate the flight director information and respond with control inputs, but it limited the terminal area noise-reduction potential. Improvements in control systems and future flight directors will allow the quieter low-nacelle flight operations to be brought nearer the terminal area. As higher levels of control augmentation and other improvements are incorporated, future pilot workload will be reduced, allowing precise, repeatable approaches to be made in a shorter time/distance interval. This will allow approaches that tend more toward the shorter VFR-type approaches.

Within the next 10 years, civil tiltrotor operations will make use of the information derived from both VFR- and IFR-type acoustic testing to combine handling qualities and acoustic constraints in a highly efficient flight director and flight control computer. This will allow the noise-reduction potential of the tiltrotor to be applied in precise, repeatable approaches to the public benefit.



a) Approach profile characteristics.

b) Sound exposure level ground contour.

Figure 16. Example of approach with high pilot workload

2.2.2.9 Summary of Noise Abatement Approaches

The 3° approach and the 3° to 9° segmented approach profile A were the quietest approaches tested during this program. This is primarily due to the fact that these approaches maintained a lower 60° nacelle angle until about one-mile from the landing point. The combination of nacelle angle, airspeed, and glideslope appear to orient the rotors tip-path-planes to a condition that avoids blade-vortex interactions (BVI). All the other approaches presented here began at a nacelle angle of 80° from nearly three miles out, thus putting the rotors into a flight condition more likely to generate BVI noise. The 3° approach was the quietest around the hover pad, probably due to the lower descent rate requiring less of a decelerating flare to achieve hover at the landing point. The 3° to 9° segmented approach profile A was much quieter at the far up-range distances, probably because the aircraft was on the quieter 3° glideslope and about 300 feet higher in altitude than the 3° approach due to the steeper 9° segment towards the end of the approach. For the final portion of the approach, from about 2500 feet up-range to the landing point, the 3° to 9° segmented approach profile A was quieter on and around the centerline of the flight path while the 3° approach was quieter to the sidelines. This was probably because the 3° to 9° approach had transitioned to the noisier condition of the 9° glideslope. Comparing the 3°, 6°, and 9° approaches, the 6° approach tended to be the loudest on centerline at all up-range distances measured; however, this difference was usually quite small. The noise levels to the sidelines at all up-range distances increased with increasing glideslope angle. Noise levels around the landing point also increased with increasing glideslope angle. Overall, the 9° approach was the loudest and the 3° approach was the quietest. The 3° to 9° segmented approach profile B was quieter than the 6° and 9° approaches, but not by much except at the far up-range distances. This approach was much noisier than the 3° to 9° segmented approach profile A, probably because the higher 80° nacelle angle employed during the early portion of the approach put the rotor into a condition where BVI noise was generated.

3. CONCLUSION

3.1 Summary

Acoustic measurements were obtained for the XV-15 tiltrotor aircraft performing a large number of different approach profiles. Approaches were flown over a large area microphone array to measure the noise footprint of the XV-15 during different flight approach profiles. Five different approach profiles are presented in this report – 3°, 6°, and 9° approaches and two different 3° to 9° segmented approaches. The 6° approach was considered the "baseline" approach and all other approaches are compared against it. Handling qualities considerations played an important role in the design of the noise abatement approach profiles. A newly developed flight director allowed much more repeatable and precise profiles to be flown but simultaneously limited the noise abatement potential due to the high pilot workload required to fly these IFR type approaches. The data set was found to have good repeatability for matching flight conditions with a variation of ±0.6 dBSEL on centerline for level flyovers and ±2.25 dBSEL variation on centerline, 3750 feet back from the landing point for 6° approaches.

The 9° approach was found to be the loudest approach with an average SEL about 1.5 dB higher than that for the 6° baseline approach. The 6° approach had the highest centerline levels at all up-range distances while the 9° approach tended to have the highest sideline levels. The 3° approach was found to be one of the quieter profiles overall with an average SEL about 3.25 dB down from the baseline approach. However, most of the noise reduction was found to the sidelines with very little, if any, noise reduction on the centerline except at the farthest up-range measurement locations. One of the 3° to 9° segmented approaches was found to be the quietest approach with an average 3.6 dBSEL reduction compared to the baseline approach. This approach provided the greatest noise abatement benefits at the farther up-range locations during the 3° approach angle segment and less benefits close to the landing point during the 9° segment. Noise reductions of as much as 10 dBSEL were found at the up-range centerline locations about one mile out and beyond. The average SEL reduction for all microphones from 4000 to 8000 feet up-range was almost 7 dB.

The noise reductions measured reflect lower BVI noise generation that results from more favorable nacelle angle/airspeed/glideslope schedules. The data strongly suggests approaching at nacelle angles no higher than about 60°, and maintaining these low nacelle angles for as long as possible. This has been demonstrated in the quieter 3° approach and the 3° to 9° segmented approach profile A cases, where there is a clear reduction in source noise due directly to the judicious scheduling of the nacelle angle and airspeed. Nacelle angle is a configuration control (and primary acceleration control at low speed) unique to the tiltrotor that can be used to achieve noise abatement. The results also clearly indicate that nacelle angle/airspeed/glideslope schedules can be developed to achieve maximum noise abatement for all profiles envisioned for IFR type approaches.

Repeatability of optimum noise abatement approach profiles can be nearly assured with use of a flight director and flight control computer. Further improvements in the tiltrotor's flight director and simulation studies will allow this optimization to take place in all segments of the approach and landing.

3.2 Future Plans

An additional contracted effort has been initiated to further examine the XV-15 data gathered in this and the 1995 test to determine which approach procedures are most effective in reducing terminal area noise. This information was used in formulating the plan for the similar test conducted in 1999.

An experimental means of simultaneously viewing the time-varying acoustic and aircraft state data has been developed by Bell. This PC-based system grew out of a similar UNIX – based one developed earlier under NASA funding. It is called PC-LANDD, for PC-based Large Array Noise Data Display, and a sample screen is shown in Figure 17. This new tool has the capability of displaying time-varying noise contours, along with aircraft position and acoustically relevant flight parameters such as nacelle angle, airspeed, roll, pitch, yaw, flap position, rotor speed, and descent rate.

It is anticipated that PC-LANDD can be applied in examining data from the 1995 and 1997 test to assist in determining the cause-effect relationships between specific flight procedures and the resultant noise.

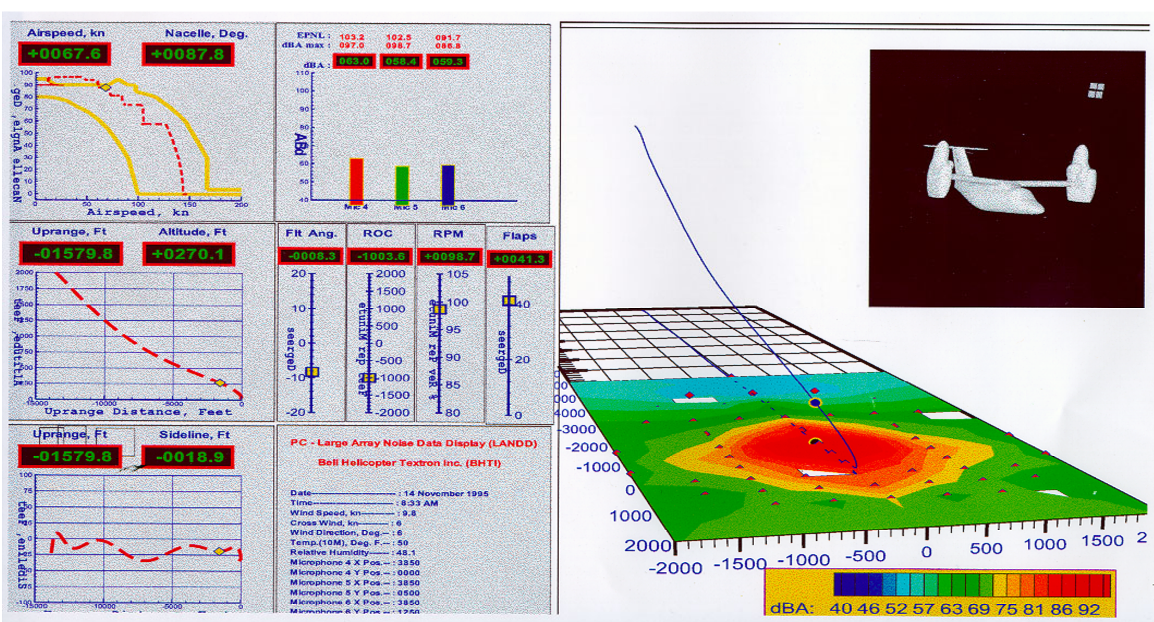


Figure 17. Large Array Noise Data Display

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1) Maisel, M. D., “XV-15 Tiltrotor Aircraft Research Aircraft Familiarization Document,” NASA TMX-62,407, January 1975.

2) Edwards, Bryan D, “External Noise of the XV-15 Tiltrotor Aircraft,” NASA Contractor Report 187463, May 1991.

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4) Klein, P.D., and Nicks, C.O., “Flight Director and Approach Profile Development for Civil Tiltrotor Terminal Area Operations,” Presented at the American Helicopter Society 54th Annual Forum, Washington, DC, May 1998.

5) Decker, W. A., “Piloted Simulator Investigations of a Civil Tilt-Rotor Aircraft on Steep Instrument Approaches,” AHS 48th Annual Forum, Washington, DC, June 1992.

6) Gray, D., Wright, K., and Rowland, W., “A Field-Deployable Digital Acoustic Measurement System,” Presented at Technology 2000 (Proceedings published as NASA CP 3109, Vol.2), Washington, DC, November 27-28, 1990.

7) Lucas, M.J., and Marcolini, M.A., “Rotorcraft Noise Model,” Presented at the AHS Technical Specialists’ Meeting for Rotorcraft Acoustics and Aerodynamics, Williamsburg, VA, October 28-30, 1997.

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APPENDIX A

LIST OF TEST PERSONNEL

Table A1. Tiltrotor Noise Test Personnel

June-July, 1997 @ SSC, Waxahachie, Texas

Association	First Name	Last Name	Responsibilities During Test
Bell	John	Brieger	Acoustics
Bell	Sandy	Liu	Acoustics
Bell	Rick	Riley	Acoustics
Bell	Mike	Shaw	Data Operations
Bell	Kelly	Spivey	Data Operations
Bell	Mark	Stoufflet	Data Operations
Bell	Jim	Wilson	Dynamics
Bell	Bill	Martin	Flight Test Engineer
Bell	Alan	Adamson	Instrumentation
Bell	Jerry	Walker	Instrumentation Technician
Bell	Jerry	Pickard	Logistics
Bell	John	Ball	Pilot
Bell	Roy	Hopkins	Pilot
Bell	Colby	Nicks	Project Engineer - Flight Test
Bell	Bryan	Edwards	Project Engineer -Acoustics
Bell	Ken	Cogdill	XV-15 Support Crew
Bell	Harry	Durand	XV-15 Support Crew
Bell	Fred	Major	XV-15 Support Crew
Bell	Ken	Mitchell	XV-15 Support Crew
Bell	Weldon	Rhea	XV-15 Support Crew
Lockheed	Charlie	Smith	NASA- LaRC Data Analysis
NASA-Ames	Bill	Decker	Handling Qualities
NASA-Ames	Rick	Simmons	Pilot
AMCOM-JRPO	David	Conner	Project Manager/Engineer
NASA-LaRC	Michael	Marcolini	Project Engineer
NASA-LaRC	John	Cline	Test Engineer
NASA-LaRC	Arnold	Mueller	Test Engineer
Wyle Labs	Tom	Baxter	NASA Instrumentation
Wyle Labs	Nicholas	Karangelen	NASA Instrumentation
Wyle Labs	Virgilio	Marcelo	NASA Instrumentation
Wyle Labs	Keith	Scudder	NASA Instrumentation
Wyle Labs	John	Swain	NASA Instrumentation
Wyle Labs	Diane	Suever	NASA Instrumentation - (Weather Balloon)

APPENDIX B

MICROPHONE LOCATIONS – SURVEYED POINTS

Table B1: Mic Locations - Surveyed Points

Microphone Number	X Grid	Y Grid	Z Grid	Latitude				Longitude			
				Dir	Deg	Min	Sec	Dir	Deg	Min	Sec
1	1000	0	641.55	N	32	19	10.761	W	96	54	25.85900
2	1000	1000	649.95	N	32	19	20.367	W	96	54	28.65600
3	500	0	640.69	N	32	19	9.574	W	96	54	31.51500
4	500	500	644.55	N	32	19	14.377	W	96	54	32.91400
5	250	0	642.76	N	32	19	8.981	W	96	54	34.34300
6	0	250	654.89	N	32	19	10.788	W	96	54	37.87200
7	0	500	649.38	N	32	19	13.190	W	96	54	38.57000
8	0	1000	647.05	N	32	19	17.992	W	96	54	39.97000
9	0	1500	645.02	N	32	19	22.795	W	96	54	41.36700
10	-250	100	646.11	N	32	19	8.754	W	96	54	40.28000
11	-1000	0	659.14	N	32	19	6.011	W	96	54	48.48300
12	-1000	500	656.33	N	32	19	10.814	W	96	54	49.88100
13	-1000	1000	657.21	N	32	19	15.618	W	96	54	51.28000
14	-1000	1500	667.02	N	32	19	20.421	W	96	54	52.68000
15	-1000	2000	679.78	N	32	19	25.223	W	96	54	54.07700
16	-2500	0	643.8	N	32	19	2.449	W	96	55	5.45100
17	-2500	500	648.7	N	32	19	7.252	W	96	55	6.84900
18	-2500	1000	653.75	N	32	19	12.055	W	96	55	8.24700
19	-2500	1500	658.94	N	32	19	16.857	W	96	55	9.64600
20	-2500	2000	666.38	N	32	19	21.659	W	96	55	11.04400
21	-3750	0	663.54	N	32	18	59.481	W	96	55	19.59100
22	-3750	250	666.38	N	32	19	1.882	W	96	55	20.29000
23	-3750	500	667.97	N	32	19	4.283	W	96	55	20.99000
24	-3750	1000	665.49	N	32	19	9.087	W	96	55	22.38700
25	-3750	1500	669.25	N	32	19	13.888	W	96	55	23.78700
26	-3750	2000	680.43	N	32	19	18.692	W	96	55	25.18600
27	-5000	0	655.48	N	32	18	56.512	W	96	55	33.73100
28	-5000	500	658.41	N	32	19	1.314	W	96	55	35.12900
29	-5000	1000	654.13	N	32	19	6.119	W	96	55	36.52800
30	-5000	1500	652.16	N	32	19	10.919	W	96	55	37.92700
31	-6000	0	631.09	N	32	18	54.137	W	96	55	45.04100
32	-6050	500	636.45	N	32	18	58.800	W	96	55	47.07000
33	-5950	1000	638.47	N	32	19	3.840	W	96	55	47.34000
34	-6950	0	646.92	N	32	18	51.870	W	96	55	55.86000
35	-7000	750	647.32	N	32	18	58.965	W	96	55	58.45700
36	-7000	1250	654.55	N	32	19	3.767	W	96	55	59.85100
37	-7750	0	661.88	N	32	18	49.970	W	96	56	4.92000
Hover Pad	**0**	**0**	**643.53**	N	32	19	**8.387**	W	96	**54**	**37.17200**
NASA Van N71	340	780	646.42	N	32	19	16.686	W	96	54	35.507
NASA Van N72	-1780	680	653.46	N	32	19	10.691	W	96	54	59.207
NASA Van N99	-4380	800	666.82	N	32	19	5.668	W	96	55	28.956
BHTI Van	-6500	700	650	N	32	19	36.489	W	96	53	28.48868
Control Site	-25	6035	723.1	N	32	20	6.293	W	96	54	54.36509
East light	2000	0	649.73	N	32	19	13.136	W	96	54	14.54700

NOTE: Positive X is Easterly
Positive Y is
Positive Z is Up

NOTE: Flight Path Ran Approx. 70.3°. True.
(Approx. 76.1°. Magnetic)

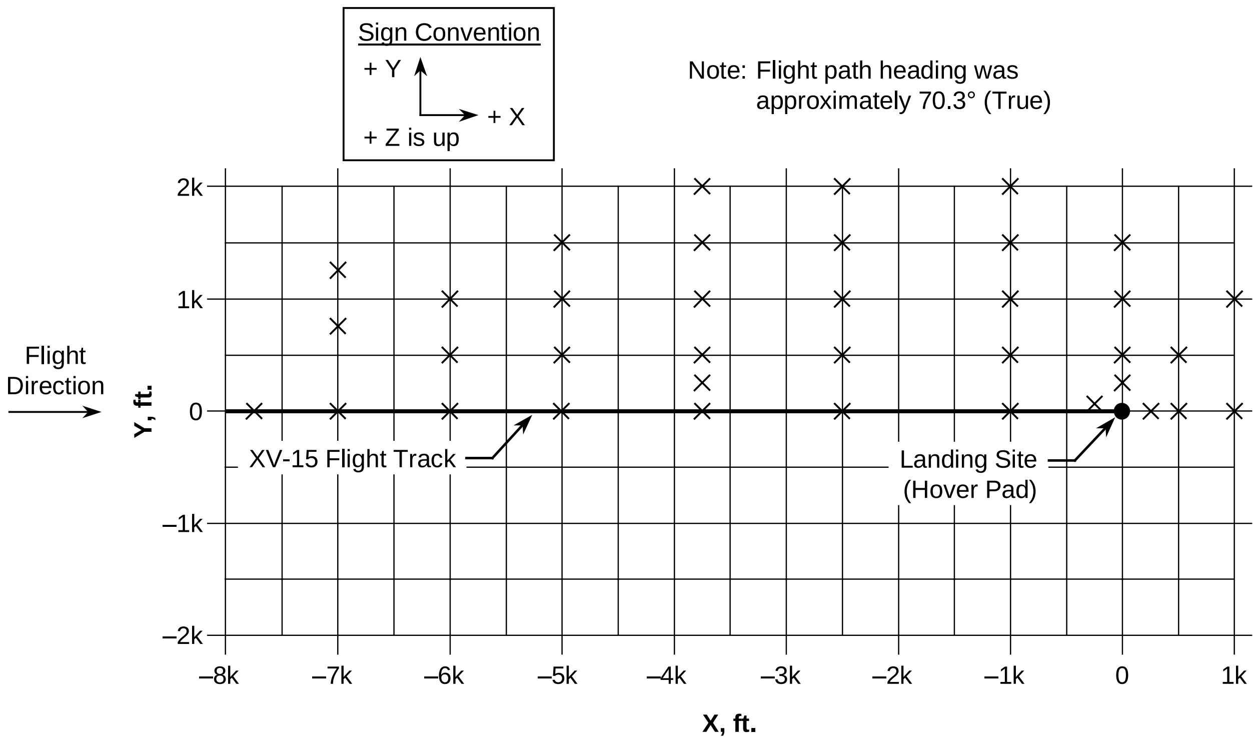

Figure B-1. Graphic Presentation Of Microphone Positions

APPENDIX C

METEOROLOGICAL CONDITIONS

Table C-1. Weather for XV-15 Testing

NOTE: site elevation = 730 ft above sea level

Run #	Avg Alt m ASL	Avg Alt m AGL	Avg Alt ft AGL	Avg Press mb	Avg Press in. Hg.	Avg Temp °C	Avg Temp °F	Avg RH %	Avg Speed mps	Avg Speed Kts	Avg DIR Deg
start 106	941.0	211.0	772.08	966.075	28.528	21.32	70.37	88.58	2.00	3.88	274.3
start 107	804.5	74.5	324.36	981.350	28.979	22.11	71.79	88.18	2.20	4.27	268.6
start 109	917.5	187.5	695.00	968.725	28.606	21.65	70.97	88.58	3.05	5.92	237.3
start 110	900.5	170.5	639.24	970.600	28.661	21.59	70.86	88.58	3.05	5.92	258.1
start 111	738.5	8.5	107.88	988.780	29.198	23.21	73.77	83.48	0.45	0.87	357.5
start 112	882.5	152.5	580.20	972.855	28.728	21.88	71.38	88.58	2.70	5.24	247.1
start 113	1016.5	286.5	1019.72	957.995	28.289	21.00	69.80	88.58	2.60	5.05	247.3
start 114	864.0	134.0	519.52	975.395	28.803	26.83	80.29	59.36	2.05	3.98	125.8
start 115	756.0	26.0	165.28	988.410	29.187	29.19	84.53	24.04	1.65	3.20	241.5
start 116	842.0	112.0	447.36	977.855	28.876	27.19	80.93	57.36	2.35	4.56	245.4
start 117	983.0	253.0	909.84	962.360	28.418	25.49	77.88	68.12	2.35	4.56	222.1
start 118	983.5	253.5	911.48	962.305	28.417	25.84	78.50	66.10	3.70	7.19	324.0
start 119	865.5	135.5	524.44	975.225	28.798	26.72	80.10	59.52	3.50	6.80	234.0
start 120	745.5	15.5	130.84	988.530	29.191	28.49	83.27	49.50	3.20	6.21	258.5
start 121	874.5	144.5	553.96	974.235	28.769	27.34	81.20	53.67	2.95	5.73	240.0
start 122	855.0	125.0	490.00	968.865	28.610	23.77	74.78	94.00	10.25	19.91	195.3
start 123	766.5	36.5	199.72	978.690	28.900	23.07	73.52	94.00	5.00	9.71	165.0
start 124	819.5	89.5	373.56	972.755	28.725	23.46	74.22	94.00	10.00	19.42	198.1
start 125	748.0	18.0	139.04	980.715	28.960	23.16	73.69	94.00	6.45	12.53	185.6
start 126	842.0	112.0	447.36	970.260	28.651	23.34	74.00	94.00	10.25	19.91	203.0
start 127	815.5	85.5	360.44	973.255	28.740	23.13	73.63	94.00	9.60	18.64	208.8
start 128	807.0	77.0	332.56	974.165	28.767	23.00	73.39	94.00	8.30	16.12	207.2
start 129	1027.5	297.5	1055.80	957.935	28.287	26.44	79.58	66.00	4.80	9.32	225.3
start 130	998.5	268.5	960.68	961.085	28.380	26.77	80.18	66.00	5.70	11.07	216.8
start 131	851.5	121.5	478.52	977.070	28.853	28.31	82.96	66.00	5.00	9.71	215.8
start 132	751.0	21.0	148.88	988.150	29.180	29.76	85.57	65.93	3.85	7.48	221.9
start 133	891.5	161.5	609.72	972.745	28.725	28.70	83.65	66.00	5.40	10.49	246.4
start 134	1002.5	272.5	973.80	960.660	28.368	27.60	81.68	66.00	5.05	9.81	220.1
start 135	898.0	168.0	631.04	971.985	28.702	28.73	83.71	66.00	5.55	10.78	219.8

Table C-1. Weather for XV-15 Testing (Continued)

NOTE: site elevation = 730 ft above sea level

Run #	Avg Alt m ASL	Avg Alt m AGL	Avg Alt ft AGL	Avg Press mb	Avg Press in. Hg.	Avg Temp °C	Avg Temp °F	Avg RH %	Avg Speed mps	Avg Speed Kts	Avg DIR Deg
start 136	779.0	49.0	240.72	985.070	29.089	29.95	85.90	63.48	5.90	11.46	199.8
start 138	1016.5	286.5	1019.72	955.480	28.215	23.40	74.11	100.00	8.05	15.63	212.0
start 139	946.0	216.0	788.48	963.225	28.444	24.00	75.20	100.00	8.70	16.90	191.6
start 140	936.0	206.0	755.68	964.270	28.475	24.23	75.61	100.00	8.85	17.19	189.1
start 141	895.0	165.0	621.20	968.810	28.609	24.85	76.73	100.00	9.00	17.48	204.4
start 142	852.0	122.0	480.16	973.520	28.748	25.65	78.17	100.00	8.55	16.60	189.8
start 143	790.0	60.0	276.80	980.375	28.950	26.03	78.85	100.00	8.30	16.12	200.9
start 144	728.5	-1.5	75.08	987.145	29.150	26.62	79.91	95.54	7.85	15.24	187.4
start 145	865.5	135.5	524.44	976.615	28.839	24.37	75.86	76.33	4.15	8.06	284.9
start 146	977.0	247.0	890.16	964.280	28.475	23.86	74.94	77.49	5.30	10.29	257.9
start 147	1010.0	280.0	998.40	960.665	28.368	23.80	74.84	78.82	5.10	9.90	259.8
start 148	887.5	157.5	596.60	974.165	28.767	24.33	75.79	75.42	4.90	9.52	287.7
start 149	757.0	27.0	168.56	988.700	29.196	24.25	75.64	82.74	3.40	6.60	306.4
start 154	783.0	53.0	253.84	989.260	29.212	26.59	79.86	69.10	4.85	9.42	324.4
start 155	828.5	98.5	403.08	984.195	29.063	26.20	79.15	70.70	5.40	10.49	297.1
start 156	984.5	254.5	914.76	967.000	28.555	25.53	77.95	68.59	5.55	10.78	295.1
start 157	983.0	253.0	909.84	967.115	28.559	25.15	77.27	76.49	5.90	11.46	312.0
start 158	842.0	112.0	447.36	982.685	29.018	26.36	79.44	69.62	5.05	9.81	310.0
start 159	763.5	33.5	189.88	991.430	29.277	27.80	82.04	65.40	4.85	9.42	285.2
start 160	883.0	153.0	581.84	978.170	28.885	26.67	80.01	68.90	3.65	7.09	280.9
start 161	827.0	97.0	398.16	981.035	28.970	25.49	77.87	83.22	7.95	15.44	263.5
start 162	877.5	147.5	563.80	975.450	28.805	25.52	77.94	80.67	9.45	18.35	277.3
start 163	816.0	86.0	362.08	982.300	29.007	25.54	77.96	84.04	6.35	12.33	271.5
start 164	786.5	56.5	265.32	985.565	29.103	25.83	78.49	84.86	3.75	7.28	261.3
start 165	917.0	187.0	693.36	971.115	28.677	25.26	77.46	82.78	7.80	15.15	265.5
start 166	932.5	202.5	744.20	969.440	28.627	25.45	77.81	79.26	9.50	18.45	271.3
start 167	907.5	177.5	662.20	972.140	28.707	26.07	78.92	77.35	8.90	17.28	281.8
start 168	930.0	200.0	736.00	973.220	28.739	25.32	77.58	81.46	6.00	11.65	281.8
start 169	855.5	125.5	491.64	981.460	28.982	25.91	78.63	80.66	5.00	9.71	262.9

Table C-1. Weather for XV-15 Testing (Concluded)

NOTE: site elevation = 730 ft above sea level

Run #	Avg Alt m ASL	Avg Alt m AGL	Avg Alt ft AGL	Avg Press mb	Avg Press in. Hg.	Avg Temp °C	Avg Temp °F	Avg RH %	Avg Speed mps	Avg Speed Kts	Avg DIR Deg
start 170	754.0	24.0	158.72	992.710	29.314	27.48	81.46	74.77	4.15	8.06	263.2
start 171	818.5	88.5	370.28	985.555	29.103	27.10	80.78	76.76	4.50	8.74	275.7
start 172	940.0	210.0	768.80	972.140	28.707	26.03	78.85	79.25	4.70	9.13	266.7
start 173	1013.5	283.5	1009.88	964.080	28.469	25.41	77.74	79.81	4.35	8.45	245.5
start 174	901.5	171.5	642.52	976.415	28.833	26.52	79.73	75.56	3.95	7.67	258.3
start 175	774.0	44.0	224.32	990.525	29.250	27.95	82.31	71.24	2.95	5.73	229.0
start 176	831.0	101.0	411.28	984.235	29.064	27.84	82.11	69.72	3.90	7.57	255.1

APPENDIX D

CANDIDATE FLIGHT PROCEDURES

NOTE: Flight procedures are presented graphically here for only the primary runs (indicated with a "P" in Appendix E)

NOTE: In the figures, #/# signifies nacelle angle / airspeed. Example: 85/70 indicates an 85° nacelle angle at 70 knots airspeed.

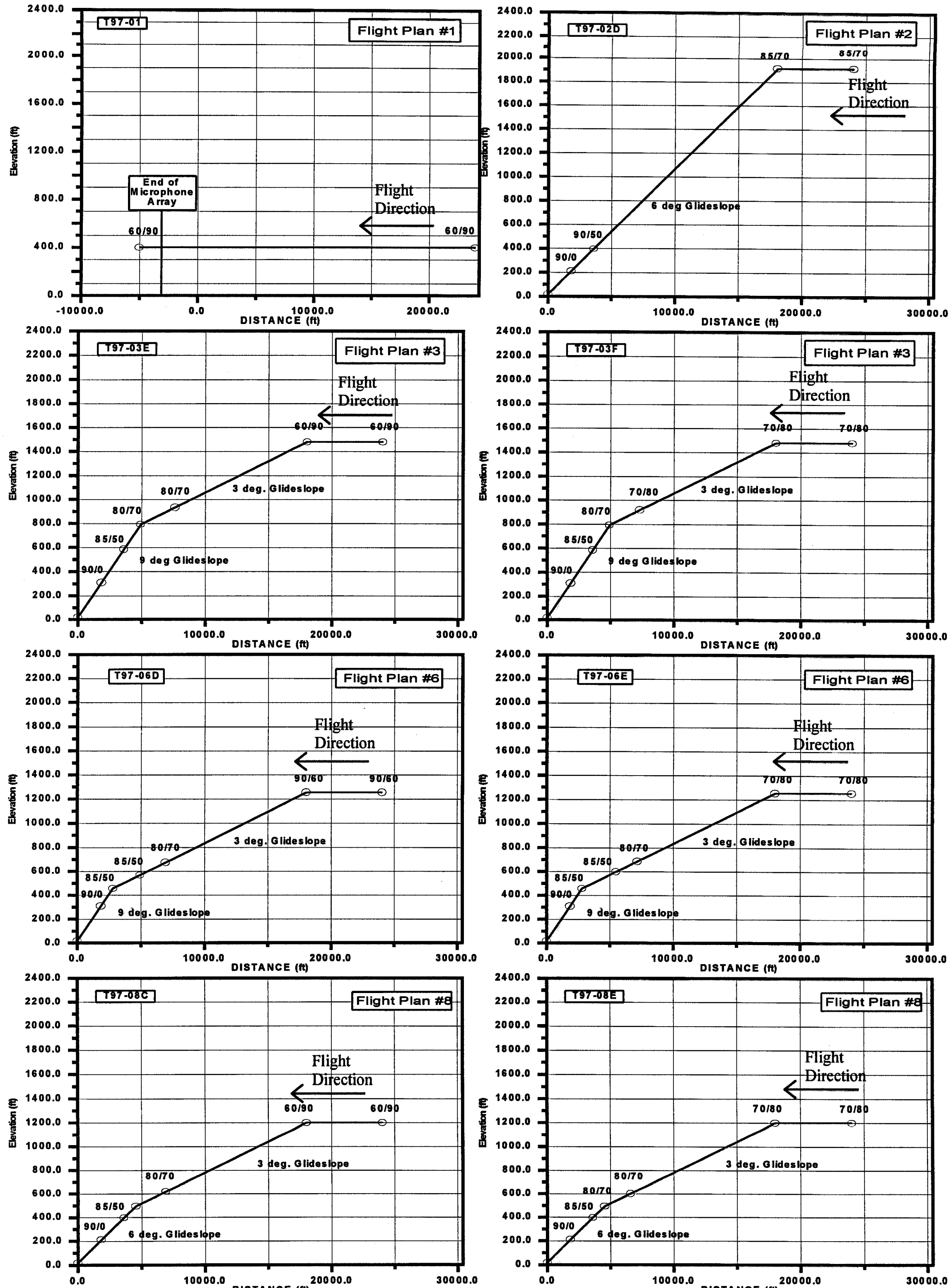

Figure D-1. Flight Profile Path Descriptions

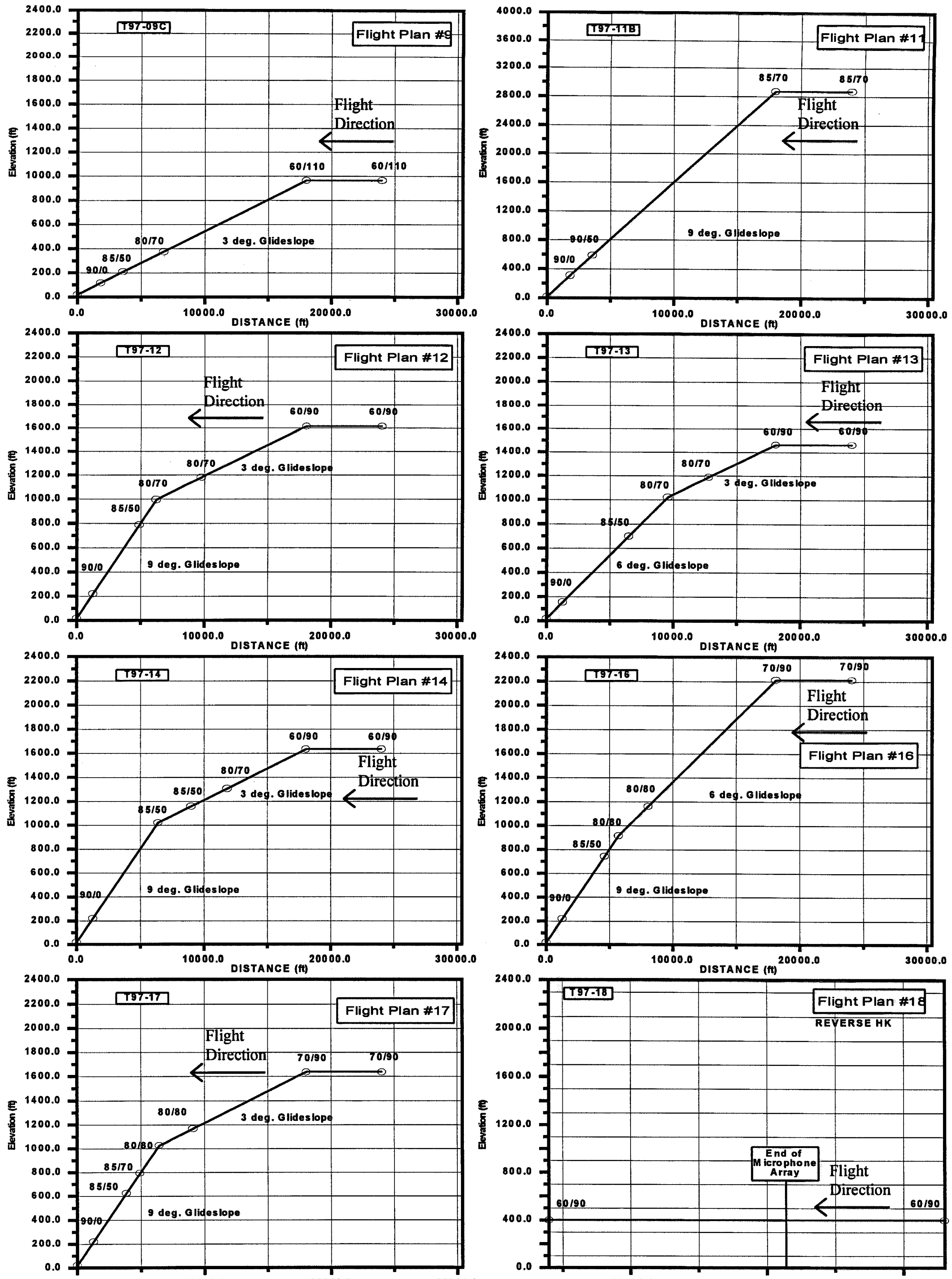

Figure D-1. Flight Profile Path Descriptions (Continued)

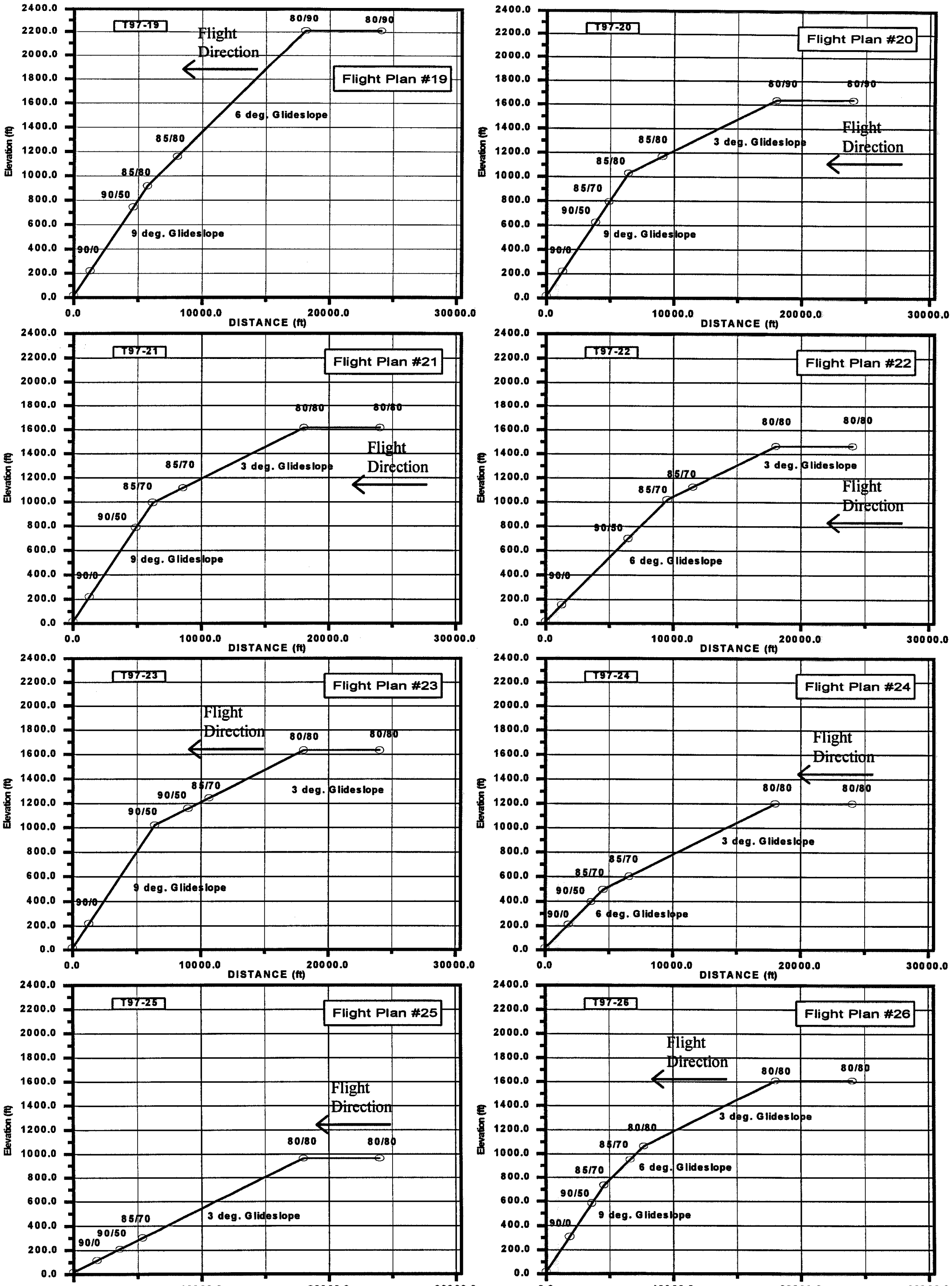

Figure D-1. Flight Profile Path Descriptions (Concluded)

APPENDIX E

SEQUENTIAL LIST OF FLIGHTS CONDUCTED – TEST LOG

XV-15

Table E-1. Test Log – Sequential List of Test Conditions

	A/C	Date	Local Time	XV-15 Flt #	NASA Run #	BHTI Ship Rec #	Profile #	Comments	BDE Notes
	XV-15	06-07-97	952	266	-		1		
	XV-15	06-07-97	1012	266	-		1		
	XV-15	06-07-97	1017	266	101	13	1		visual flt-tk.901
	XV-15	06-07-97	1023	266	102	14	1		902
	XV-15	06-07-97	1034	266	103	15	02D		106
	XV-15	06-07-97	1042	266	104	16	11B	wing 12-14 KT @ 110 deg	wind 14/109 12/120 19/96
	XV-15	06-07-97	1048	266	105	17	09C		
	XV-15				901		99		
	XV-15				902		99		ambient record
	XV-15	06-11-97	703	267A	106	12	1	low winds – good conditions	lo wind – good cond.
	XV-15	06-11-97	710	267A	107	13	02D		
	XV-15	06-11-97	720	267A	108	14	02D	abort	
	XV-15	06-11-97	723	267A	109	14	02D		
P*	XV-15	06-11-97	733	267A	110	15	02D	baseline condition	USED AS BASELINE
	XV-15	06-11-97	743	267A	111	16	11B	fixed wing prop audible	with SV-15 at 2000 ft, fixed wing over ctrl trailer
P*	XV-15	06-11-97	752	267A	112	17	11B	fixed wing prop audible	with XV-15 at 12k, fixed wing prop. Flew N. to S. at 5000 ft
	XV-15	06-11-97	801	267A	113	18	11B?		bad mic #36 (low). Plot run 112 instead
	XV-15				903		99		RTB-DELAY INRETURNING-INDY PROBLEM
	XV-15				904		99		ambient rec. – pilots Ray Hopkins/John Ball
	XV-15	06-11-97	1102	267B	114	25	1		
	XV-15	06-11-97	1110	267B	115	26	09C		
	XV-15	06-11-97	1117	267B	116	27	09C	came in low mic 10 & 36 dead	came in low mic 6 dead
P*	XV-15	06-11-97	1125	267B	117	28	09C	mics 10 & 36 dead	mic 6 dead eliminated mic 36 from plots, estimated mic 10@ 112 db for plot
	XV-15	06-11-97	1133	267B	118	29	06C	Difficulty with glideslope – unacceptable Handling Qualities	Difficulty with glideslope - unacceptable
	XV-15	06-11-97	1140	267B	119	30	06C	Difficulty with glideslope – unacceptable Handling Qualities	
	XV-15	06-11-97	1148	267B	120	31	08	unacceptable H.Q. – too nose high	unacceptable – too nose high
	XV-15	06-11-97	1156	267B	121	32	08	unacceptable H.Q. – too nose high	unacceptable – too nose high

*Indicates a "Primary" flight condition – Appendix D graphically illustrates these selected approaches

Table E-1. Test Log – Sequential List of Test Conditions (Continued)

	A/C	Date	Local Time	XV-15 Flt #	NASA Run #	BHTI Ship Rec #	Profile #	Comments	BDE Notes
	XV-15				905		99		
	XV-15				901		99	Wind at 400 ft – 20 kt, 190 deg	
	XV-15	06-12-97	701	268	122	3	12A	Wind at 400 ft – 20 kt, 190 deg	John Ball began approach too high-on later. Wind at 400 ft – 20 kt , 190 deg
P*	XV-15	06-12-97	710	268	123	4	12A	Good	Good
P*	XV-15	06-12-97	720	268	124	5	14A		
	XV-15	06-12-97	729	268	125	6	12A	Wind at 300 ft – 20 kt, 190 deg	Pilot attempted cond 12-wind at 300 ft – 20 kt, 190 deg
	XV-15	06-12-97	737	268	126	7	08D	Mic 35 questionable	
P*	XV-15	06-12-97	746	268	127	8	06C		
	XV-15	06-12-97	755	268	128	9	01A		
	XV-15				902				
	XV-15				901		99		
	XV-15	06-19-97	1003	269	129	9	01A	winds at 500 ft. – 10 kt, 200 deg	winds at 500 ft. – 10 kt, 200 deg
P*	XV-15	06-19-97	1013	269	130	11	02D	10 kt tail wind	12-15 kt tail wind
	XV-15	06-19-97	1019	269	131	12	16A	12-15 kt tail wing-good HQ	12-15 kt tail wind
	XV-15	06-19-97	1026	269	132	13	17A	16 kt tail wind – good HQ	16 kt tail wind
	XV-15	06-19-97	133	269	133	14	16A		
	XV-15	06-19-97	1040	269	134	15	17A	15 kt tail wind	15 kt tail wind
	XV-15	06-19-97	1046	269	135	16	16A	some jet noise at beginning of record	
P*	XV-15	06-19-97	1054	269	136	17	17A	thermals occurring, but not too bad	
	XV-15				902		99		
	XV-15	06-24-97			901		99		
	XV-15	06-24-97			137				
	XV-15	06-24-97	1047	270	138	8	01A		
P*	XV-15	06-24-97	1053	270	139	9	08E or 2	Approach started high. Profile 08E or 02D???Wind at 600: 17 kt @200 deg	(xv initiated approach high – wrong software?)
	XV-15	06-24-97	1100	270	140	10	03E		
P*	XV-15	06-24-97	1107	270	141	11	013		
P*	XV-15	06-24-97	1115	270	142	12	06E		
	XV-15	06-24-97	1123	270	143	13	018A	All sites report good data, this was a reverse housekeeping run	
	XV-15	06-24-97	1127	270	144	14	03F		
	XV-15				902		99		

*Indicates a “Primary” flight condition – Appendix D graphically illustrates these selected approaches

Table E-1. Test Log – Sequential List of Test Conditions (Continued)

	A/C	Date	Local Time	XV-15 Flt#	NASA Run#	BHTI Ship Rec#	Profile#	Comments	BDE Notes
	XV-15				901		99		
	XV-15	06-25-97	646	271	145	2	01A		KH
	XV-15	06-25-97	653	271	146	6	16A	Add 108 sec to the start time, all sites rpt good data	“ray’s 352”
	XV-15	06-25-97	701	271	147	4	16A		
p*	XV-15	06-25-97	709	271	148	5	16A		
p*	XV-15	06-25-97	717	271	149	6	03C	Mic 37 reported bad	
	XV-15		725		150		03C	Mic 37 reported bad	
	XV-15				902		99		
	XV-15		823		151		01A		
	XV-15		830		152		06E		
	XV-15				153		06E		
	XV-15				903		99		
	XV-15		10						
	XV-15	06-26-97	951	272	154	8	01A		
	XV-15	06-26-97	958	272	155	9	20A		
	XV-15	06-26-97	1006	272	156	10	20A		
p*	XV-15	06-26-97	1013	272	157	11	20A		
	XV-15	06-26-97	1021	272	158	12	19A		
	XV-15	06-26-97	1028	272	159	13	19A		
p*	XV-15	06-26-97	1035	272	160	14	19A		
	XV-15				901		99		
	XV-15		0						
	XV-15		0		901		99	Mic # 10 bad,	
	XV-15	6-27-97	743	273A	161	2	01A	Mic # 10 bad	
	XV-15	6-27-97	802	273A	162	3	23A	Mic #4 questionable	
p*	XV-15	6-27-97	811	273A	163	4	23A	Mic #4 questionable	Bad mic #14 (high) used value averaged between mic 13 & 15 for plot
	XV-15	6-27-97	820	273A	164	5	26A	Mic #24 bad	
	XV-15	6-27-97	828	273A	165	6	26A		Bad mic #14 (high) used value averaged between mic 13 & 15 for plot
p*	XV-15	6-27-97	836	273A	166	7	02D		Bad mic #14 (high) used value averaged between mic 13 & 15 for plot

*Indicates a “Primary” flight condition – Appendix D graphically illustrates these selected approaches

Table E-1. Test Log – Sequential List of Test Conditions (Concluded)

	A/C	Date	Local Time	XV-15 Flt #	NASA Run #	BHTI Ship Rec #	Profile #	Comments	BDE Notes
p*	XV-15	6-27-97	843	273A	167	8	25A		
	XV-15				902		99		
	XV-15	06-27-97	945	273B	168	11	01A		
	XV-15	06-27-97	951	273B	169	12	24A	Pilot has positive comments	
	XV-15	06-27-97	959	273B	170	13	24A	Pilot happy with work load	
p*	XV-15	06-27-97	1006	273B	171	14	24A	Pilot comments ditto	
	XV-15	06-27-97	1013	273B	172	15	22A	Pilot rpts acceptable until 90 deg nacelle	
p*	XV-15	06-27-97	1021	273B	173	16	22A	Pilot reports some sight turbulence	
p*	XV-15	06-27-97	1028	273B	174	17	26A		
p*	XV-15	06-27-97	1035	273B	175	18	25A	Pilot reports some slight turbulence	
	XV-15	06-27-97	1043	273B	176	19	21A		

*Indicates a "Primary" flight condition – Appendix D graphically illustrates these selected approaches

APPENDIX F

PILOT COMMENTS

PILOT COMMENTS (XV-15)

Flight #:	**Comments:**
266-104	On approach: “Not a bad initial”
266-105	On return trip to base: “actually was a great first time” “helps coming in visual the last few feet” “went good for first time”
267a-106	“A nice easy fly over point. Very comfortable HQR....” “Very low pilot workload” “I pretty much used a lot of visual line up on that one, just to maintain the line up”
267a-107	“A very comfortable 6 deg. approach” “again, not much of a workload here anywhere other than initially capturing the glide slope” “that was a good approach. The initial workload was just in the glide slope intercept.” “Overall approach I give an HQR of 3” “was very, very controllable, adequate performance, very tolerable work load there” “very satisfactory approach.” “Very comfortable, very nice approach”
267a-108	ABORTED
267a-109	“Very low workload...” “ low work load approach”
267a-110	“HQR 3” “overall a pretty good approach”
267a-111	“Felt pretty comfortable to me all the way through” “very controllable, achieved adequate performance, tolerable workload” “satisfactory approach.”
267a-112	On approach: “this isn’t bad at all, not making many control movements.” “Pretty good approach, HQR 3.” “HQR 3 right down to the point you start bringing it to a hover.” “Last tenth (of a mile) end up with a lot of cues and workload, but due more to the lateral positioning cues.”
267a-113	During approach: “nice workload” “performance was pretty good. Overall HQR 3”

PILOT COMMENTS (XV-15) (Continued)

Flight #:	**Comments:**
267b-115	"Approach was controllable, adequate performance and tolerable work load, last part of the approach was unacceptable definitely warrants improvement. Primarily due to the deceleration rate (following the cues would have led to trouble)"
267b-116	"...and again, a similar thing happened there, following the flight director. Gonna have to go visual at about 6 tenths (miles out) to keep from getting too low." "OK, same comments. At about 6 tenths (miles) in, not too good at the 85 deg nacelle prompt. Have to ignore it and fly visually from there." "Markedly deficient in that particular approach" "everything is all at once too." "Flaps, gear, nacelle all at once" "everything right one after the other." "Following the cues is a real workload inducer."
267b-117	"I tend to come in 6-7 degrees nose high because I can't use 95 deg. nacelle. I would prefer to use that all the way in, but" "OK, normal entry into the glide slope. Glide slope was fine up until 85 deg. nacelle, at which point I took over visually because it required such big power reduction and we do have the power lines in front of us." "90 deg. nacelle prompt late, sooner transition would prevent needing the extra flare."
267b-118	On approach: "OK on this approach, 9 deg., we're too nose high for me. About 7 deg. nose high immediately and I don't like this." "Way too nose high attitude. More flaps would help here." "ABORT because of pitch attitude and coming in visual from about 4 tenths (mile) from here on." "This one's completely unacceptable." "I don't like that high nose attitude coming into a hover." "I find that one really ridiculous, I don't see any point in continuing that one." "A lot of safety issues with that. attitude is too way high. I never fly the aircraft like that, never." "Lets give that a try (flaps at 40 deg. throughout), would probably help a bit." "Not adequate performance at all, not satisfactory work, got worse at the end" "unacceptable" "basic approach algorithm is no good."

PILOT COMMENTS (XV-15) (Continued)

Flight #:	Comments:
267b-119	On approach: “excessive buffeting on this descent in the glide slope.” “I find this attitude objectionable, am back at 60 deg. nacelle and 80 knots. We should not be here in a descent. 10 deg. nose high not good at all.” “Here is where I’d really like to go to 95 deg. nacelle just to keep this attitude down a little bit. I don’t like it when I can’t see over the nose as I come into a hover.” “I call that approach completely unacceptable.” “Profile keeps too high a nacelle angle for the speed. don’t like the buffeting vibrations on the descent.” “Is unsatisfactory and warrants improvement.” “Overall configuration not acceptable.”
267b-120	On approach: “10 deg. nose high, I don’t like the attitude here.” “I find this terribly objectionable, attitude wise.” “Can’t see a thing.” “Handling quality deficiency right in this area.” “This is ridiculous, 60 deg. nacelle 74 knots” “I have to ABORT this, attitude is too high at 3 tenths (mile). I’ll go visual.” “Didn’t get the 40 deg. flaps prompt until 1 tenth (mile).” “That whole profile is also totally unacceptable.” “From an attitude stand point, handling quality stand point and just the basic profile is unacceptable.” “Just too slow for 60 (deg.) nacelle. Profile is wrong.” “Way too much work load at the bottom, need to spread things out.
267b-121	“Unacceptable even at 40 deg. flaps at that profile and with all the work load associated with all the gates so close together, had to go visual at 7 tenths because pitch attitude was too high.” “Uncomfortable following the cues.”

RETURNING TO BASE 12:02pm “well these last 3 approaches we did this afternoon, I wouldn’t buy any one of them.” “Wouldn’t use any one of them.” “All we did was eliminate them.” “They warrant massive changes” “way too nose high.” “Too much work load too, can’t decel. on a comfortable profile.”

ON THE GROUND 12:06pm “no problems, just found out some of those approaches weren’t any good.” “those weren’t too keen.”

PILOT COMMENTS (XV-15) (Continued)

Flight #:	Comments:
268-122	"OK, I don't like this one already, because the pitch attitude is 10 degrees nose high." "No correction for drift on this" "75 knots. I can't believe it. 75 knots and 60 nacelle." "(need) big power reduction here..." "big power reductions here... right after that nacelle prompt" "didn't like the big power reductions in there" "yeah, I don't like those either too." tolerable workload? "no, some deficiencies require improvement. I think the large power changes were difficult to keep up with, especially after the nacelle changes." "Most difficulty was in the large power changes after the nacelle" "we need to slow down the nacelle movement it looks like to make the power changes more tolerable."
268-123	"72 knots, some buffeting here" "yeah, this is not a place to be." "70 knots. buffeting." "Again, the most difficult phase was the big power changes with changes in glide slope and nacelle angle going to the 90 degrees." "Almost felt uncomfortably slow up that high, especially with the cross wind. So you need to take a look at the wind limitations on that." "I did feel like we picked up an uncomfortably high sink rate going to the 9 degree glide slope before I got the rate of descent under control."
268-124	"We're about 12 degrees nose high." "Yeah, this is not very much fun here." "Lots of work with the power reduction and then starting at the 6 and then to the 9" "uncomfortably high nose attitudes on approach even to the point of buffeting down to 70-69 knots."
268-125	"Got good buffeting here at 70 knots, 11 degrees nose up." "Develop high sink rates and the combination of slow speed and the cross winds makes it unacceptable to try to hold course." "Nacelle changes too quick, have to make quick big power reductions." "Every conversion is still highest workload, its not blended in well."
268-126	"13 degrees nose up, 60 knots. Its a lot of buffeting. very uncomfortable." "Yeah, its horrible. I can't see anything." "Very high nose up." "Those are all uncomfortable." "Performance attainable/tolerable workload? No." "satisfactory? No." "the most control activity was on nacelle changes. Happening too fast, can't keep up with the glide slope changes." "A lot of work load with all those changes lumped together."

PILOT COMMENTS (XV-15) (Continued)

Flight #:	Comments:
268-127	"Pitch up, starting to slow.buffeting." "I hate these approaches like this." "70 knots airspeed, lots of buffeting at 13 degrees nose up." "Adequate performance attainable/ tolerable workload? No." "couldn't keep on course because I was too much concentrating on pitch and power. Problem comes in the nacelle changes. they need to round out the profile. and the cross wind is a big issue as you slow also."
268-128	HOUSE KEEPING. "need workload reduction (for high cross winds.)"
269-130	"Was flyable and controllable. Got adequate performance." "The close in was good too. The deceleration at 200 ft was nice and smooth using 90 nacelle only (no need for more than 90 to slow.)." "Handling qualities at the end were very smooth."
269-131	"Other workload factor (besides the cross wind) was a little more rushed with the 9 degree and closure rate was pretty high at .6 that's when we used the 95."
269-132	Control prompts are later than where the pilot expected they should be. Resulted in faster and higher approach. "Workload was pretty high, we didn't get adequate performance on that one."
269-133	Late transition cues led to a high pitch at the end near the pad. "Ended up with excessive pitch attitude, could not see the landing site until visible through side window." "Would have been unacceptable. We were right at the margin of just adequate performance."
269-134	"Pretty steep" "same as time before. Weren't getting the prompts on time. Late on getting the nacelles moved. got too steep."
269-135	"Workload higher but due to late nacelle prompts"
269-136	"Noticeably more turbulence" "one of the smoother of the last two approach types." "Generally much more acceptable." "Stayed within desired for the most part."

PILOT COMMENTS (XV-15) (Continued)

Flight #:	Comments:
270-139	"Is adequate performance attainable/tolerable workload: NO" "Is satisfactory: NO" the problem was keeping course with flight director and gusts and cross wind. Not due to approach plan.
270-141	"OK, we're 12 degrees nose up, buffeting. "problems due to cross winds, gusts and flight director.
270-142	"12 deg. nose high is too high I think."
270-144	Wind/cross wind problems – turbulence "I don't know why they persist on these high nose up attitudes. I don't see what that's gaining anybody." "Well they say those 60 and 70 (degree nacelles) are quiet. 60 is the quietest nacelle angle. But we finally got them to change those. We were up to about 15 degrees nose high sometimes."
271-145	Housekeeping "was very steady point. Very minimal power changes. Airspeed slowed from 79 at 3 miles to about 74 at the end."
271-146	"Was it controllable: Yes" "adequate performance attainable/tolerable workload: Yes, in this case it was. and I believe it was because of the low wind situation, no cross winds." "Satisfactory without improvement: Yea, it just might be."
271-147	"That last one had a higher workload that last mile as far as power goes. Big power fluctuations."
271-148	"That last one was again, the workload was high, keeping the power necessary to maintain the glide slope."
271-149	"On a 3 deg glide slope now, this is comfortable." "A nice long 3 degrees here, this is easy." "I wait to use 95 (nacelle) until I'm almost at the pad, its a nice decel. on final."
271-152	"It appeared, compared to earlier flight types, that there is too much happening in the last mile and a half. Have two nacelle changes and then as you're adjusting for the second one, then you have to reduce power and go down to a 9 deg glide slope and I think that's too much work there at the bottom."

PILOT COMMENTS (XV-15) (Continued)

Flight #:	**Comments:**
272-155	(at 3 miles)"at 3 degrees. This is a very comfortable attitude right in here." "Overall comments it worked out pretty good" "all the attitudes were comfortable on that last approach"
272-156	"All the constraints are being met with a very low workload right here." "OK, same comments for that one. Everything looked like it was pretty well within constraints. Workload was reasonably low." "The attitude is good there"
272-157	"Nice comfortable 450ft per minute rate, easy" "different, worse sounding noise with this 9 degree glide slope, we can pick it up in the cockpit" "comments on that one, no different from the others."
272-158	"6 degree glide slope. A little change in sound as we lower power here for the glide slope. Can hear the difference in the sound in the cockpit."
273a-162	"3 degree glide slope here feels real comfortable." "It appeared going to 90 (kts) out there at 1.5 miles was too early for 90 nacelle, airspeed got down in the 30 kt range. Trying to maintain glide slope at that slow airspeed and maintain course was too hard."
273a-163	"At 80 nacelle we have slight buffeting at 58 kts in our glide slope." "OK, once again we got real slow out here, we went to 90 degrees." "Dramatic power reductions required when you enter the 9 deg. glide slope at that slow speed." "Well, it still brings us out at a comfortable position." "OK that last one (23) workload was tolerable until we made two nacelle changes back to back. When we got to 90, the aircraft slowed dramatically, still wanted to pitch up and needed large power reduction to maintain glide slope. And we did have buffeting and picked up in descent rate as we came in to the 9 decree slope." "So under these conditions (a cross wind was present) I would not want to use that approach again."
273a-164	"Overall that flight plan 26 was more tolerable from a workload point."
273a-165	"Was more comfortable the second time because I knew what to expect for the power changes." "It felt better overall than the first one."

PILOT COMMENTS (XV-15) (Continued)

Flight #:	**Comments:**
273a-166	"Nice steady glide slope, tolerable workload."
273a-167	"Tolerable workload coming down that glide slope (a bit shallow for local obstacles- power lines)."
273b-169	"This glide slope is tolerable, 65 kts airspeed, level pitch attitude." "(going to 90 nac.)..better than those other ones." "That was pretty nice." "Overall that was an acceptable approach. The deceleration at 90 nac. did not seem to cause problems as it did that one time. our speed was kept up around 40 kts. and it was a nice transition at around 6/10 mile."
273b-170	"Flight plan 24 seems to work out fine. The nacelle changes and the glide slope intercepts had enough time that you could get your power set up to where it should be before the next evolution occurred. When we went to 90 nac we were still maintaining 40 kts. Which did not seem to cause a problem and it brought us out at 3/10 mile on a nice flight path."
273b-171	"Comments are similar to that last one. If you had at least one practice one, then you can anticipate the power changes before the next requirement comes up and then its manageable there at the end. Again the 90 nac did not seem to cause any problems, it gives a nice point at which to go visual at 3/10 mile."
273b-172	"That last one was acceptable until we went to 90 nac and then it seems that if the co-pilots speed gets below about 40 kts. We end up with some large power changes. (Other problems related to cross winds too)." "If I compare flight plan 24 and 22, 24 is more acceptable under conditions today because we held the 90 nac. until 6/10 mile instead of a half mile farther out."
273b-173	"At 90 nac. 35 kts. we have some buffeting." "Comments are same as the first"
273b-174	"That was a good one. Went 3 to 6 to 9 degrees, but there was enough time between changes required that it worked out OK. Tolerable workload."
273b-175	"That was a low workload coming down at that 3 degree glide slope. (Low for local power line obstruction though...)"

PILOT COMMENTS (XV-15) (Concluded)

Flight #:	**Comments:**
273b-176	"That was a good approach, felt real comfortable. Were some large power changes required in transition from the 3 to the 9 (degree glide slopes), but I felt that and the nacelle changes were spaced out enough that I could compensate for them." "Went to 90 nacelle at 8/10 mile which seemed a little too far out this time, 6/10 or 5/10 always seem to work better."

REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188

1. AGENCY USE ONLY (*Leave blank*)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	April 2003	Technical Memorandum

4. TITLE AND SUBTITLE
XV-15 Tiltrotor Aircraft: 1997 Acoustic Testing

5. FUNDING NUMBERS
WU 576-03-15-10

6. AUTHOR(S)
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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
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Hampton, VA 23681-2199

U.S. Army Aviation and Missile Command
Aeroflightdynamics Directorate
Joint Research Programs Office
NASA Langley Research Center
Hampton, VA 23681-2199

8. PERFORMING ORGANIZATION REPORT NUMBER
L-18265

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
National Aeronautics and Space Administration
Washington, DC 20546-0001
and
U.S. Army Aviation and Missile Command
Moffett Field, CA 94035-1000

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
NASA/TM-2003-212151
AMCOM/AFDD/TR-03-A-001

11. SUPPLEMENTARY NOTES
Edwards: Bell Helicopter Textron, Inc., Fort Worth, TX; Conner: JRPO, Aeroflightdynamics Directorate, AMCOM, Langley Research Center, Hampton, VA.

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Unclassified-Unlimited
Subject Category 71 Distribution: Standard
Availability: NASA CASI (301) 621-0390

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*
XV-15 acoustic test is discussed, and measured results are presented. The test was conducted by NASA Langley and Bell Helicopter Textron, Inc., during June - July 1997, at the BHTI test site near Waxahachie, Texas. This was the second in a series of three XV-15 tests to document the acoustic signature of the XV-15 tiltrotor aircraft for a variety of flight conditions and minimize the noise signature during approach. Tradeoffs between flight procedures and the measured noise are presented to illustrate the noise abatement flight procedures. The test objectives were to: (1) support operation of future tiltrotors by further developing and demonstrating low-noise flight profiles, while maintaining acceptable handling and ride qualities, and (2) refine approach profiles, selected from previous (1995) tiltrotor testing, to incorporate Instrument Flight Rules (IFR), handling qualities constraints, operations and tradeoffs with sound. Primary emphasis was given to the approach flight conditions where blade-vortex interaction (BVI) noise dominates, because this condition influences community noise impact more than any other. An understanding of this part of the noise generating process could guide the development of low noise flight operations and increase the tiltrotor's acceptance in the community.

14. SUBJECT TERMS
Tiltrotor; Acoustics; Noise; Flight procedures; Noise abatement; Aircraft; Rotorcraft; Operations; SHCT; Short haul civil tiltrotor

15. NUMBER OF PAGES
63

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	UL